C3 Preliminary

See the Office of Bridges and Structures web site for archived Methods Memos listed under articles in this section.

The Methods Memos for which policies have been partially revised and/or for which document references have been updated are noted as partially revised. Any obsolete Methods Memos that apply to this section are listed at the end.

C3.1 General

C3.1.1 Policy overview

C3.1.2 Design information

C3.1.3 Definitions

C3.1.4 Abbreviations and notation

C3.1.5 References

C3.1.5.1 Direct

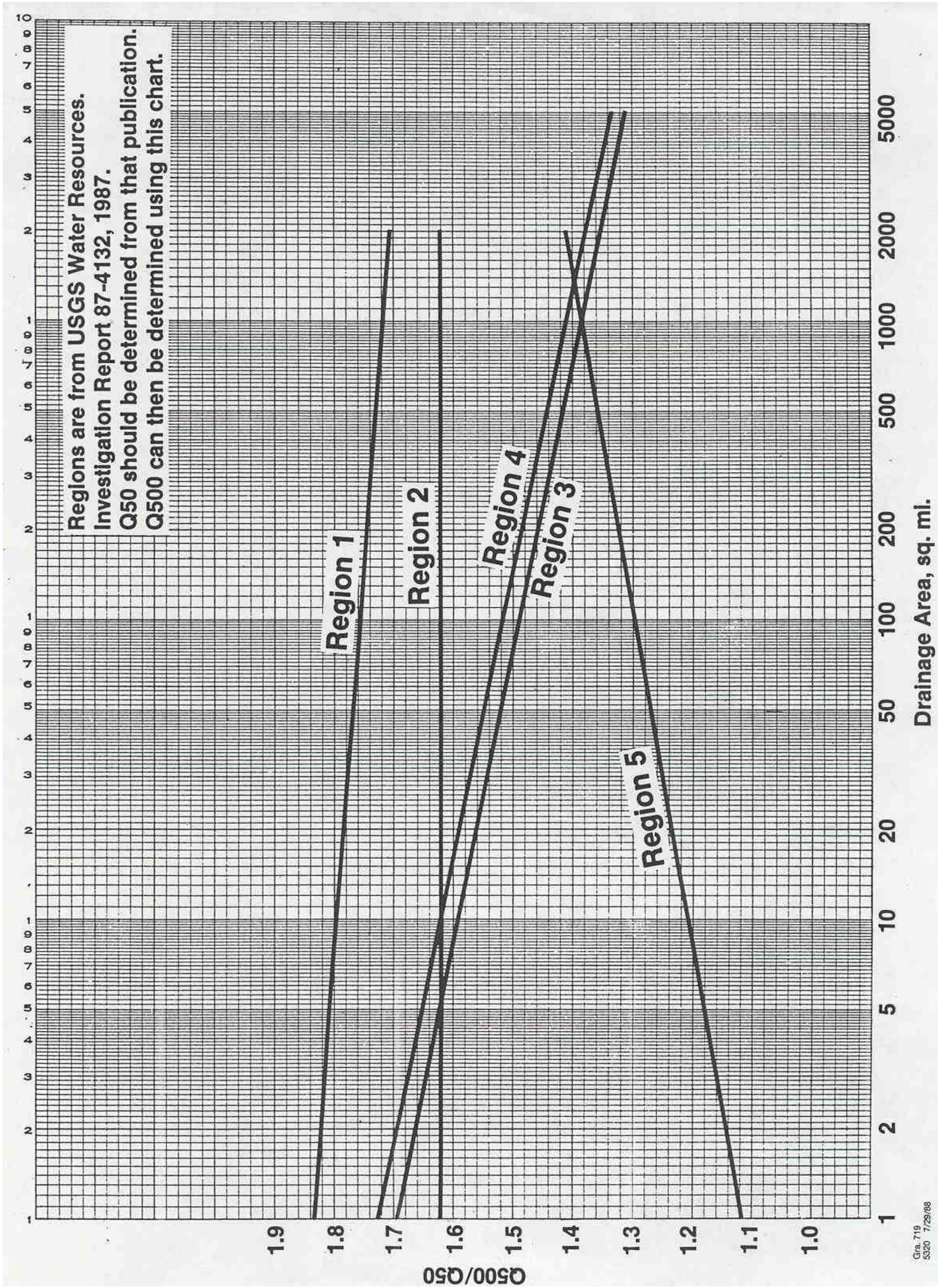
C3.1.5.2 Indirect

C3.2 Bridges

C3.2.1 Identification numbers

C3.2.2 Stream and river crossings

C3.2.2.1 Hydrology


Regions are from USGS Water Resources.
Investigation Report 87-4132, 1987.
Q50 should be determined from that publication.
Q500 can then be determined using this chart.
Region 1
Region 2
Region 3
Region 4
Region 5
Drainage Area, sq. mi.
Q500/Q50
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
1
2
5
10
20
50
100
200
500
1000
2000
5000

C3.2.2.2 Hydraulics

C3.2.2.3 Backwater

C3.2.2.4 Freeboard

C3.2.2.5 Road grade overflow

C3.2.2.6 Streambank protection

Riprap placement on streambank
22 December 2006

The following figure is taken from page 35 of the Iowa DNR's manual *How to Control Streambank Erosion (updated 2006).* The complete manual, including several pages that discuss riprap, may be downloaded from the following web site:

http://www.iowadnr.gov/water/stormwater/forms/streambank_man.pdf

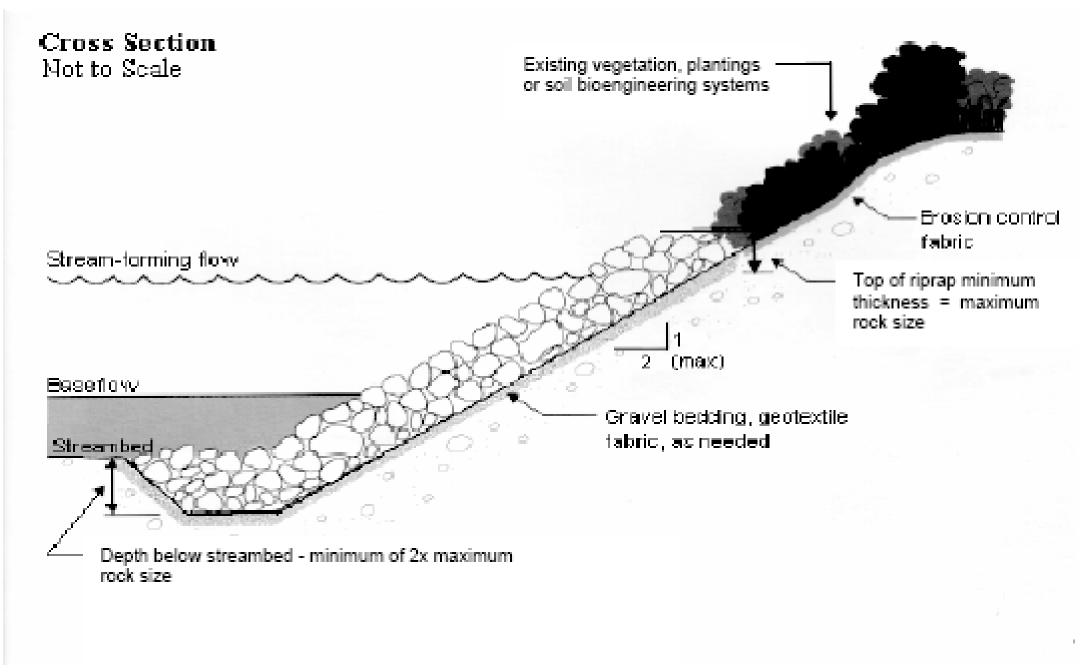


Figure 24. Cross-sectional view of riprap placement on the graded slope of a Streambank.

C3.2.2.7 Scour

Introduction

The most common cause of bridge failures in the nation is flooding, with bridge scour being the most common type of flood damage. Bridge scour is a complicated process and provides challenges to engineering analysis. Because of public safety and high replacement and repair costs, the need exists to evaluate or improve current design and maintenance practices concerning bridge foundations.

The objective in this document~~appendix~~ is to detail three items:

1. Factors that affect scour.
2. Recommendations to reduce or prevent scour effects on existing and proposed bridges.
3. Methods to estimate scour for existing and proposed structures.

Definition

A basic definition of scour is the result of erosive action of moving water as it excavates and carries away material from a streambed and banks. There are two types of scour:

1. General scour - the loss of material from most or all the bed and banks, usually caused by the road embankment encroaching onto the flood plain with resulting contraction of the flood flow (often called contraction scour).
2. Local scour – the loss of material around piers, abutments, spur dikes and embankments.

There are two conditions for contraction and local scour: clear-water and live-bed. Clear-water scour occurs when there is little to no movement of the bed material of the stream upstream of the crossing. Typical situations include most overflow bridges, coarse bed material streams, and flat gradient streams during low flow. Live-bed scour occurs when velocities are high enough to move the bed material upstream of the crossing. Most Iowa streams and rivers experience live-bed scour.

Streambed degradation, such as in the Western Iowa loess region, is considered in some documents to be scour. Even though degradation can affect structural stability like local or general scour does, the causes of degradation are of a different nature, and it will not be discussed in detail in this document.

The effects of scour are a complex problem involving geotechnical, hydraulic, and structural concerns, so decisions concerning scour should involve engineers in each of these disciplines.

Design guidelines and considerations

Numerous factors affect the stability of the bed and banks of a stream and are discussed below with some guidelines and considerations.

1. Soils

Soils with any combination of sand or silt have greater potential for scour: sand, silt, sandy silt, sandy silty clay, etc. As a general rule, according to IDOT's Soils Design Section, soils which have a blow count of ten or less are particularly susceptible.

Excessive loss of pile bearing due to scour is one cause for bridge damage or failure. However, perhaps a more common cause of failure is soil instability associated with the road embankment and bridge berm. Often a bridge berm or fill behind a high abutment has minimal factor of safety for stability. If this safety factor is reduced due to scour at the toe of the embankment, the soil may become unstable resulting in a slip failure. Damage to an abutment, pier or approach fill is a possible outcome.

For replacement structures, designing flatter berm slopes and/or placing the abutments farther from the channel will provide a greater safety factor. Then, when scour does occur, the embankment will more likely remain stable. For existing structures, protection of the berm, especially the toe, may be necessary.

2. Substructure

Generally, wider and longer piers have greater scour potential. Deeper footings and longer piles are more stable at greater scour depths. Spread footings should be used only on material highly resistant to scour such as limestone and some shales.

To maintain the integrity of the structure, do not allow scour to reduce pile bearing below a desirable safety factor that is selected by the structural or geotechnical engineer. Designing for this minimum safety factor may require designing longer piles for new bridges. For existing structures, protection of the piles may be necessary to maintain the safety factor.

New bridges should have sufficient length so that the abutments do not encroach on the channel but placed as far back from the streambank as practical. Vertical wall abutments (high abutments) have a greater potential for general and local scour as compared to the spillthrough type (integral or stub abutments).

3. Flood discharge

In the publication "Evaluating Scour at Bridges", Hydraulic Engineering Circular No. 18 (HEC-18), the FHWA recommends using a Q_{100} or lesser discharge for scour analysis, depending on which results in the most severe scour conditions. Usually the overtopping flood results in the worst scour, so check this flood (if less than the Q_{100}) and the Q_{100}.

The discharge used in scour design is generally larger than that used in hydraulic design. For example, hydraulic design guidelines for a bridge may be a Q_{25} discharge, but the scour design may use a Q_{100}. The rationale for this is that hydraulic design involves backwater and ensures that the bridge size will be adequate under normal flood conditions. In scour design, a higher discharge is used to ensure that the bridge will remain stable and will not fail or suffer severe damage during extreme flood events.

FHWA also recommends checking scour conditions for a superflood, such as a Q_{500}. If Q_{500} data is not available, HEC-18 recommends using 1.7 X Q_{100}. The safety factors for the bridge should remain above 1.0 under this flood condition. Similar to that mentioned above, $Q_{overtopping}$ may be the worst-case flood and should be used if it is less than Q_{500}.

4. Interaction between road and flood plain

A highly skewed river crossing provides a less hydraulically efficient bridge opening and therefore has a greater contraction scour potential. Also, a high ratio of overbank flow to main channel flow will result in a greater contraction scour potential. For these situations, scour can be reduced by using wing dikes and/or riprap.

Road grade overflow or overflow structures may provide relief and reduce scour potential for the main channel bridge.

5. Interaction between piers and flood flow

The width, length and type of pier (e.g., pile bents, "tee" piers) all have an effect on local scour. Closely spaced piles in a pile bent pier can act similar to a solid wall. The angle of attack of flood flow to the pier can also significantly increase scour if this angle changes due to channel meandering during the life of the bridge. For example, if the angle of attack changes from 0° to 15°, the pier scour approximately doubles. The stream's history of and future potential for meandering should be examined.

6. Debris and ice

Visual observation can be made and maintenance records can be checked to determine the history of debris and ice on the stream. Debris and ice can snag on the piers or superstructure, placing additional stresses on the bridge as well as promoting local scour. This scour can sometimes be quite significant although difficult to estimate. Therefore, for new designs, give consideration to raising the low superstructure above the low roadgrade elevation. This will allow hydraulic relief if the bridge opening becomes clogged.

Estimating scour

Procedures for estimating scour have been researched in the past 40 years in an attempt to develop reliable prediction equations. Some of these equations give reliable results, others do not. The Federal Highway Administration has attempted to find the best equations and published them in HEC-18.

HEC-18 contains equations for contraction scour, abutment scour and pier scour. The contraction scour equations are the best available equations of their type and sometimes provide reliable estimates, although these estimates still need to be evaluated considering soil types, site scour history, etc. The abutment scour equations frequently give questionable estimates. Because of comments similar to this from various states, FHWA is conducting additional research to develop new methods. At this time, IDOT recommends not using FHWA's abutment scour equations or, at most, use them with caution. However, be aware that abutment scour can occur.

Concerning pier scour, the equation in HEC-18 generally gives reliable results. However, a much simpler method that gives very similar results is found in Iowa Highway Research Board's Bulletin No. 4, “Scour Around Bridge Piers and Abutments,” by Emmett M. Laursen and Arthur Toch, May 1956. This method for estimating pier scour can be used in most cases instead of the methods in HEC-18.

1. Contraction scour estimation

See Chapter 4 of HEC-18 for detailed instructions on how to calculate contraction scour. To help explain this chapter, there are two determinations that must be made when estimating contraction scour:

- The appropriate case of contraction scour that depends on the flow interaction of the bridge to the channel and floodplain. There are four of these cases. See the figures later in this document for graphical illustrations of these cases.
- The appropriate sediment transport condition. There are two of these conditions and equations (live-bed and clear-water) that can occur in any of the four cases mentioned above.

Both determinations are explained below.

Four cases of contraction scour
Case 1 is overbank flow being forced back into the main channel due to the road fill. The majority of bridges in Iowa will be Case 1. There are three variations to Case 1, depending on the location of the abutments or abutment berms compared to the channel:

> **Case 1a** is normally used when the river channel width becomes narrower due to the bridge abutments (or berms) projecting into the channel.
>
> **Case 1b** does not involve any contraction of the channel itself, but the overbank flow area is completely obstructed by the embankment. In other words, the abutments or abutment berms are on the channel bank.
>
> **Case 1c** is when the abutments or abutment berms are set back from the channel. This case is more complex because there is both main channel flow and overbank flow in the bridge opening. Therefore, refer to discussion in Section 4.3.4 of HEC-18. More hydraulic analysis may be needed than in Cases 1a and 1b (such as WSPRO) to determine the distribution of flow in the bridge opening, i.e., what is the discharge in the main channel (Q_2) and the discharge in the overbank under the bridge ($Q_{overbank2}$).

Most Case 1 streams in Iowa will have live-bed scour. However, if the streambed material has particles larger than a sand classification, calculate V_c (see below) to determine if clear-water scour will occur instead of live-bed scour.

Case 2 is when the stream has no overbank flow. This case will be common in Western Iowa streams that are severely degraded.

Case 3 is an overflow (relief) bridge with no bed material transport, so use the clear-water scour equations. Hydraulic analysis (e.g., using WSPRO) is needed to determine the flood plain width associated with the relief opening and to determine the total flow going through the relief bridge.

Case 4 is an overflow (relief) bridge similar to Case 3 except it does have sediment transport (live-bed scour), such as over a secondary channel on the flood plain of a larger stream. Hydraulically this case is no different than Case 1 except that analysis (e.g., using WSPRO) is needed to determine the flood plain width associated with the relief opening and the portion of the total flow going through the relief bridge.

Sediment transport conditions: Live-bed scour versus clear-water scour

Before an equation is selected to estimate contraction scour, it is necessary to determine if the flow is transporting bed material. If it is, the flow will create live-bed scour. If it is not, the flow will create clear-water scour. There are different scour equations for each of these sediment transport conditions.

Most Iowa stream channels will be live-bed. In other words, the velocities in the channel will be high enough to cause movement of the soil particles in the streambed. In order to be sure if the channel is live-bed, Chapter 2 in HEC-18 gives a simple equation to calculate the ~~velocity needed~~velocity needed to cause movement of the soil:

$$V_c = 10.95\, y^{0.167} (D_{50})^{0.33}$$

where V_c = critical velocity which will transport bed materials of size D_{50} and smaller, ft/sec.
y = depth of upstream flow, feet
D_{50} = median diameter of the bed material, feet

If the velocity in the channel is greater than V_c, then the particles will move and the stream will have live-bed scour. If the velocity in the channel is less than V_c, then the particles will not move and the stream will have clear-water scour.

Most Iowa streambeds have sand or silt which results in a very low V_c. This means that even a low flood velocity will move the particles. Therefore, most Iowa streams will have live-bed scour. For example, for a medium sand with a D_{50} of 0.0012 feet (0.375 mm) and a flow depth of 12 feet, V_c is 1.8 ft/sec. Any flood with a channel velocity higher than this will cause sediment transport and therefore create live-bed scour. Even a medium gravel streambed with D_{50} of 0.039 feet (12 mm) and depth of 12 feet results in V_c of 5.7 ft/sec. Again, most Iowa streams will have a channel velocity higher than this.

In summary, as a rule of thumb, if the streambed material is larger than sand, calculate V_c and compare to expected channel velocities to determine if live-bed or clear-water scour occurs. If the material is sand or smaller, assume live-bed scour occurs.

Live-bed scour

From HEC-18, the equation for live-bed scour is as follows:

$$\frac{y_2}{y_1} = \left[\frac{Q_2}{Q_1}\right]^{0.86} \left[\frac{W_1}{W_2}\right]^{k1}$$

and $y_s = y_2 - y_1 =$ average scour depth, ft

where y_1 = average depth in the upstream main channel, ft
y_2 = average depth in the contracted section (i.e., in the bridge opening), ft
W_1 = top width of water in the upstream main channel, ft
W_2 = top width of water in the main channel in the contracted section (i.e., in the bridge opening), ft
Q_1 = discharge in the upstream main channel transporting sediment, cfs.
(Q_1 does not include upstream overbank flow)
Q_2 = discharge in the contracted channel (i.e., bridge opening), cfs
(For Cases 1a and 1b, Q_2 may be the total flow going through the bridge opening. For Case 1c, Q_2 is not the total flow through the bridge since there is also some overbank Q adjacent to the channel under the bridge.)
k_1 = exponent. Assume k_1 = 0.64 to simplify the calculations since the range for k_1 in HEC-18 Section 4.3.4 makes very little difference on calculated scour depths.

This results in the live-bed scour equation of:

$$\frac{y_2}{y_1} = \left[\frac{Q_2}{Q_1}\right]^{0.86}\left[\frac{W_1}{W_2}\right]^{0.64}$$

Simply stated, the ratio W_1/W_2 reflects contraction or expansion in the channel. The ratio Q_2/Q_1 reflects the effect of forcing overbank flow through the bridge opening.

This equation is generally used for Case 1 (when streambed consists of sand-size particles or smaller) and Cases 2 and 4. In Case 1c, the live-bed scour equation is used for the main channel contraction scour and the clear-water scour equation is used for the contraction scour near the abutment on the overbank.

Clear-water scour
From HEC-18, the equation for clear-water scour is as follows:

$$y_2 = \left[\frac{Q^2}{139\,(D_{50})^{0.67}\,(W_2)^2}\right]^{0.43}$$

and $y_s = y_2 - y_1$ = average scour depth, feet

where y_2 = depth in the bridge opening, ft
Q = discharge through the bridge opening or on the overbank portion of the bridge opening, cfs
D_{50}= median diameter of material in overbank, feet (see attached sediment size table from HEC-20)
W_2= top width of water in bridge opening or overbank width in bridge opening (set-back distance), feet
y_1 = upstream depth, ft

The average depths y_1 and y_2 are measured either in the channel for channel scour calculations or on the overbank for overbank/abutment-area scour calculations.

The clear-water scour equation is used for a few Case 1 bridges (when streambed particles are larger and, in Case 1c, when the abutment is set back a distance from the channel) and for all Case 3 bridges.

Summary of estimating contraction scour

- Determine which “case” is appropriate
- Determine if the channel has live-bed or clear-water scour
- Analyze the hydraulics
- Using the correct equation, estimate scour
- Evaluate the reasonableness of estimated scour

2. Abutment scour estimation

The equation given in Section 4.3.6 of HEC-18 is for the worst-case conditions. The equation will predict the maximum scour that could occur for an abutment projecting into a stream with velocities and depths upstream of the abutment similar to those in the main channel. In most cases, the equation will over-predict scour, especially the farther the abutment is from the channel. Do not calculate abutment scour at this time due to this questionable equation. Be aware, however, that scour at the abutments can occur.
Site experience is very important in the engineering analysis, including known scour occurrences and settlement of approach pavement which indicates soil stability problems. It is important to note that high abutments may have up to twice the scour depths as spillthrough abutments.

A conservative approach in determining effects of scour on the abutments is to assume that contraction scour is added to abutment scour when the abutment is near the channel.

Several questions should be considered for abutment stability. Is the soil scourable? What is the effect on berm stability? Are flatter berm slopes or a longer bridge needed? What is the effect on pile bearing? Are longer piles needed? Should riprap or wing dikes be used?

3. Pier scour estimation

Use “Scour Around Bridge Piers and Abutments”, Emmett M. Laursen and Arthur Toch, Iowa Highway Research Board, Bulletin No. 4, 1956, for most cases.

Figure 39 in Bulletin No. 4 is the basic design curve for pier scour. IDOT determined an equation from this curve:

$$\left(\frac{y'_s}{w_p}\right) = 1.485\left(\frac{y_1}{w_p}\right)^{0.314} \qquad \text{Equation 1}$$

where

y'_s , unfactored depth of scour, ft
y_1 , unscoured depth of flow, ft
w_p , width of pier column, ft

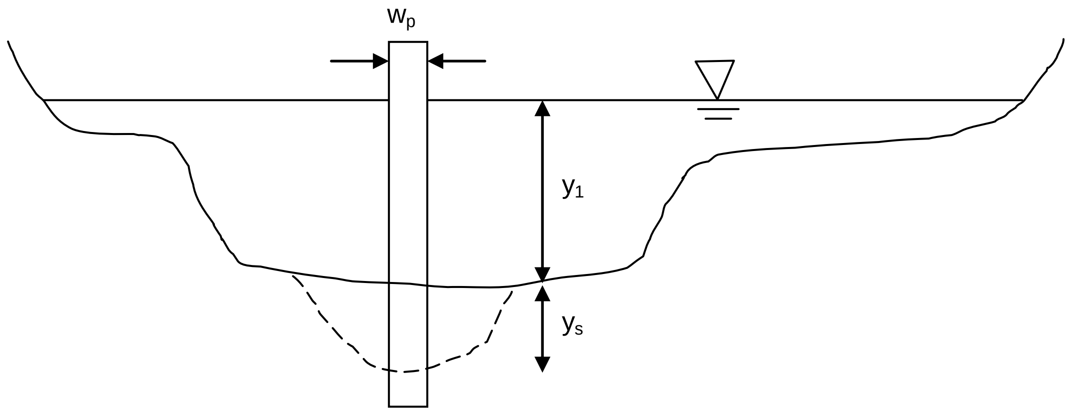
Equation 1 is then substituted into the basic equation, resulting in Equation 2 below:

$$y_s = (K)\ (y'_s) = (K)\ (w_p)\ \left(\frac{y'_s}{w_p}\right)$$

$$y_s = 1.485\ (K)\ (w_p)\left(\frac{y_1}{w_p}\right)^{0.314} \qquad \text{Equation 2}$$

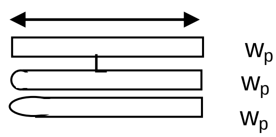
where y_s is depth of scour, ft
K, a pier coefficient (either K_a or K_s),
K_s, coefficient for pier nose shape (see below). Use only if angle of attack = 0.
K_a, coefficient for angle of attack if angle is not zero (see table below).

Equation 2 should be used to calculate pier scour.



If angle of attack is zero, use one of the following values for K_s , the coefficient for the shape of the upstream nose of the pier (adapted from Bulletin No. 4). Use this K_s value in Equation 2 in place of K. These values show that the better the "rounding" of the pier nose, the lower the pier scour.

Rectangular	1.0
Semicircular	0.9
Elliptic	0.8



If angle of attack is not zero, use the following table adapted from Figure 39 in Bulletin No. 4 to determine K_a. In this table, L = length of pier, and w_p = width of pier. Use this K_a value in Equation 2 in place of K. The values in the table show that as the angle of attack increases, the pier scour increases dramatically. For example, for a pier L/ w_p of 8, if the angle of attack changes from 0° to 15°, the factor K_a changes from 1.0 to 2.0, doubling the calculated pier scour.

Design Factors (K_a) for Piers Not Aligned With Flow

L/w_p / Angle of Attack	4	6	8	10	12	14
0°	1.0	1.0	1.0	1.0	1.0	1.0
5°	1.2	1.3	1.3	1.5	1.6	1.6
10°	1.4	1.5	1.7	1.9	2.1	2.3
15°	1.5	1.8	2.0	2.2	2.5	2.7
20°	1.7	2.0	2.3	2.5	2.8	3.0
25°	1.8	2.2	2.5	2.8	3.1	3.5
30°	1.9	2.4	2.7	3.1	3.4	3.8
35°	2.0	2.5	2.9	3.3	3.7	4.0
40°	2.1	2.7	3.1	3.6	4.0	4.3
45°	2.2	2.8	3.3	3.8	4.2	4.6

See Scour Calculation Sheet to assist in pier scour estimation. Other subjects concerning pier scour discussed in more detail are found in Section 4.3.5 of HEC-18:

- Pier scour for exposed footings and exposed pile groups under a footing
- Pier footings that are above normal streambed

- Multiple columns in a pier (e.g., a pile bent pier)
- Pressure flow scour
- Scour from debris
- Width of pier scour holes

Summary of estimating pier scour:

- Analyze hydraulics
- Estimate scour
- Evaluate the reasonableness of the estimated scour
- Add pier scour to contraction scour to obtain total scour
- Determine action steps such as countermeasures or design features of the bridge

Coding for the Structure Inventory and Appraisal (SI&A)

See the attached pages from FHWA's "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges" to determine what rating should be given to each bridge. All countermeasures (SI&A Item 113 coded as "7") should be monitored in future years by bridge inspectors.

Countermeasures: reducing the effects of scour

Generally, a new bridge should be designed to withstand scour without countermeasures, especially when the countermeasures cannot be easily inspected. For example, riprap protecting a pier in the channel is difficult to inspect, but a wing dike in the overbank is easily inspected and repaired. Countermeasures will be used most commonly on existing bridges that are scour critical. See HEC-18, Chapter 7, for an in-depth discussion of when and how to use countermeasures.

In summary, listed below are common considerations to reduce scour on the bridges. Some items may be relevant only to existing bridges; others may be relevant only in the design phase of a structure.

- Use longer piles.
- Set the pier or abutment footings lower. However, lengthening piles is generally preferred due to lesser cost.
- Place riprap around the pier, abutment, berm slope, or spur dike or across the entire streambed. Riprap is an easy and often inexpensive way to protect a bridge.
- Build abutments as far from the streambank as possible.
- Remove debris from piers.
- Wing dikes (a.k.a., spur dikes, guide banks) provide for a more hydraulically efficient bridge opening and force the scour to occur on the dike, which is expendable, rather than on the bridge itself.

More expensive solutions can be considered in some instances:

- Place sheet piling to protect existing piers or abutments.
- Underpin the foundation.
- Replace with a new bridge.
- Construct an additional span.
- Overflow (relief) bridges can be used on flood plains that have substantial overbank flow. This provides relief for the main channel bridge. However, be aware that these overflow structures are particularly susceptible to deep scour. Twenty to thirty feet of scour is not uncommon.
- Provide for roadgrade overflow which is a "relief valve" to the bridge opening during extreme flood events and can prevent or minimize damage to the bridge. A disadvantage to roadgrade overflow is potential hazard to the traveling public when water is over the road. These factors need to be weighed by the engineer when considering other factors such as traffic volumes, traffic speeds and costs.

Following are some design guidelines for sizing riprap and placing wing dikes as countermeasures. The recommendations concerning riprap are **not** intended to determine if it is needed, rather only how to properly size riprap.

1. Riprap at abutments.

Section 7.5.1 in HEC-18 gives several equations for sizing riprap at abutments. Considering these equations and past experience, IDOT recommends simplifying riprap design to the following:

When riprap is needed for countermeasure and the toe of the abutment berm or the vertical abutment is approximately 75 feet or less from the top of the bank, use the average velocity through the entire bridge opening to size the riprap. When the toe of the abutment berm or the vertical abutment is approximately 75 feet or more from the top of the streambank, use the average velocity in the overbank portion of the bridge opening.

When riprap is needed and the determined average velocity is less than approximately 8 feet per second, use IDOT's Class E riprap (D_{50} of 90 pounds). When the determined average velocity is greater than approximately 8 feet per second, use the Class B gradation which is heavier than Class E (D_{50} of 275 pounds.

2. Riprap at piers.

From Section 7.5.1 in HEC-18~~, ,~~, the equation for sizing riprap at piers reduces to the following (assuming specific gravity of 2.65 for riprap):

$$D_{50} = \frac{(K\,V)^2}{153.6}$$

where D_{50} = median stone diameter, feet
K = coefficient for pier shape (1.5 for round-nose pier, 1.7 for square-nose pier)
V = average velocity approaching pier, ft/sec

To determine V, multiply the average channel velocity (Q/A) by a coefficient that ranges from 0.9 for a pier near the bank in a straight uniform reach of the stream to 1.7 for a pier in the main current of flow around a bend.

The D_{50} for IDOT's Class E riprap is 90 pounds or approximately 1.0 foot diameter and will be adequate for many situations. From the above equation, this diameter will tolerate a velocity of 8.3 ft/sec for round-nose piers and 7.3 ft/sec for square-nose piers.

When the adjusted velocity exceeds this and riprap is needed as a countermeasure, consider using Class B riprap. This has a D_{50} of 275 pounds which is approximately 1.5 feet in diameter and will tolerate a velocity of approximately 10 ft/sec for round-nose piers and 9 ft/sec for square-nose piers. This gradation should be adequate in almost all situations where the standard gradation is not adequate.

According to HEC-18, the width of the riprap around the pier should at least twice the pier column width. However, on several countermeasure projects, IDOT has placed a much wider layer (25') around the entire pier. The riprap should be placed at or below the streambed so as not to create a greater obstruction to flow. HEC-18 recommends a thickness for the pier scour protection layer of 3 x D_{50} or greater. IDOT has used thicknesses of three and four feet on previous projects. Either guideline seems reasonable.

3. Wing dikes

Use Office of Design's ~~IDOT Road~~ Standard Road Plan RL-3. See C3.2.2.7.5.3 for~~Appendix B of "Guidelines for Preliminary Design of Bridges and Culverts" has~~ a tablepage to determine the length of wing dikes. See also HEC-20 or HDS No. 1 for further guidance.

References

1. "Evaluating Scour at Bridges", Hydraulic Engineering Circular No. 18, Federal Highway Administration, Second Edition, April 1993.
2. "Evaluating Scour at Bridges", Hydraulic Engineering Circular No. 18, Federal Highway Administration, Third Edition, November 1995.
3. "Scour Around Bridge Piers and Abutments", Emmett M. Laursen and Arthur Toch, Iowa Highway Research Board, Bulletin No. 4, May 1956.
4. "Hydraulics of Bridge Waterways", Hydraulic Design Series No. 1, Federal Highway Administration, March 1978.
5. "Design of Riprap Revetment", Hydraulic Engineering Circular No. 11, Federal Highway Administration, 1989.
6. "Stream Stability at Highway Structures", Hydraulic Engineering Circular No. 20, Federal Highway Administration, February 1991.
7. "Stream Stability at Highway Structures", Hydraulic Engineering Circular No. 20, Federal Highway Administration, Second Edition, November 1995.
8. "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges", Federal Highway Administration, December 1995.

SCOUR CALCULATION SHEET

LOCATION

County_________________ Hwy. No.___________Des. No. ________________
Maint. No. _____________ FHWA No.__________
Stream________________ Drain. Area_______sq. mi.
Twp______ Range_______ Section_____
Prepared by____________ Date_________________

BRIDGE DESCRIPTION

Size and Type____
Pier
Type_______________ Width__________ft Shape Coeff (K_s)________
Angle of Attack _____ Coeff (K_{al})_______
Pile Type___________ Pile Length below Str.Bed_____ Pile Tip Elev.______
Abutment
Type_______________ Pile Type________Pile Length_________
Pile Tip Elev.________ Berm Slope_______(proposed or existing)

STREAM INFORMATION

Exist. Streambed Elev.______ Stream Slope______ft/mi
n-values: LOB__________ Channel_____________ROB________________
Soils: Type __________________ Depth* ________ D_{50} __________ft
Type __________________ Depth* ________
Type __________________ Depth* ________
Type __________________ Depth* ________ *below streambed
Streambed Degradation
At this site _____________________ feet since _______ year
At other known sites _____________ feet since _______ year
Estimated future degradation _______feet

HYDROLOGIC/ HYDRAULIC INFORMATION

Low road elev. ______________
Methodology used to determine: Q _____________ Water surface elev. ___________

	Q_{100}	Q_{500} or $Q_{overtopping}$
Discharge (Q), cfs	____________	_____________
Water surface elev.	____________	_____________
y_1, depth in main channel, ft	____________	_____________
Vel. in main channel, fps	____________	_____________

CONTRACTION SCOUR

$V_c = 10.95\ y^{0.167}\ D_{50}^{0.33}$ = _______________ ft/sec. If V_c < average channel velocity, use live-bed scour equation. If V_c > average channel velocity, use clear-water scour equation.

Live-bed scour

Generally, used for Cases 1a, 1b, 2, and 4, and also for the main channel scour portion of Case 1c. See Section 4.3.4 in HEC-18.

$$\frac{y_2}{y_1} = \left[\frac{Q_2}{Q_1}\right]^{0.86} \left[\frac{W_1}{W_2}\right]^{0.64}$$

	Q_{100}	Q_{500} or $Q_{overtopping}$
Q_2, discharge in the contracted channel, cfs	_____________	_____________
Q_1, discharge in the upstream main channel, cfs	_____________	_____________
W_1, top width of the upstream main channel, ft	_____________	_____________
W_2, top width of the main channel in contracted section (i.e., bridge opening), ft	_____________	_____________
y_1, ave. depth in upstream main channel, ft	_____________	_____________
y_2, ave. depth in contracted section, ft	_____________	_____________
$y_s = y_2 - y_1$ = ave. scour depth, ft	_____________	_____________

Clear-water scour

For Case 3 and the overbank area of the bridge opening for Case 1c. Occasionally used for Cases 1a, 1b, 1c (main channel portion), and 2.
See Section 4.3.4 in HEC-18.

$$y_2 = \left[\frac{Q^2}{139\,(D_{50})^{0.67}\,(W_2)^2}\right]^{0.43}$$

	Q_{100}	Q_{500} or $Q_{overtopping}$
_____ y_2, depth in bridge opening, ft	___________	_____________
Q, discharge through bridge opening or on overbank portion of bridge opening, cfs	___________	_____________
D_{50}, median diameter of material in overbank, ft	___________	_____________
W_2, top width of bridge opening or overbank width in bridge opening, ft	___________	_____________
y_1, upstream depth, ft	___________	_____________
$y_s = y_2 - y_1$ = ave. scour depth, ft	___________	_____________

Is this contraction scour depth realistic?
Is the soil scourable?
What is the effect on berm stability (including any abutment scour)?
Are longer abutment piles or a flatter abutment berm needed?
Should riprap or wing dikes be used?
Other comments?

PIER SCOUR

Use "Scour Around Bridge Piers and Abutments", Emmett M. Laursen and Arthur Toch, Iowa Highway Research Board Bulletin No. 4, 1956, for most cases. Use Equation 2 below and previous discussion in the text. Also, see Section 4.3.5 in HEC-18 for more discussion on estimating pier scour.

$$y_s = 1.485\,(K)\,(w_p)\left(\frac{y_1}{w_p}\right)^{0.314} \qquad \text{Equation 2}$$

where y_s, depth of scour, ft
- y_1 , unscoured depth of flow, ft
- w_p, width of pier column, ft
- K, a pier coefficient (either K_s or K_a),
- K_s, coefficient for pier nose shape (see values in text). Use only if angle of attack = 0.
- K_a, coefficient for angle of attack if angle is not zero (see table in text).

	Q_{100}	Q_{500} or $Q_{overtopping}$
y_1, ft	________	________
w_p, ft	________	________
K (either K_a or K_s)	________	________
y_s, ft (from Equation 2)	________	________

TOTAL SCOUR AT PIER = pier scour (y_s) + contraction scour (y_s)

y_s, ft (pier)	________	________
y_s, ft (contraction)	________	________
Total scour, ft	________	________
Normal streambed elev.	________	________
Scour elevation	________	________

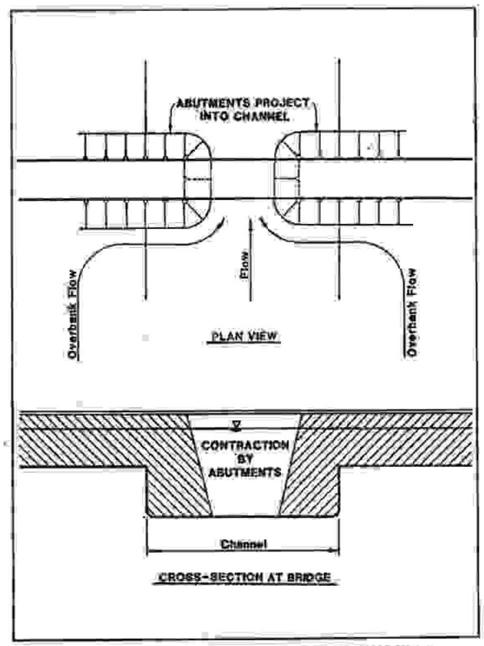
Is y_s or the total scour depth at the pier realistic?
Is the soil scourable?
What is the effect on pile stability?
Should riprap or other countermeasures be used?
What is the rating for SI&A Item 113?
Other comments?

Sediment Grade Scale, from "Stream Stability at Highway Structures", Hydraulic Engineering Circular No. 20, Federal Highway Administration, Second Edition, November 1995.

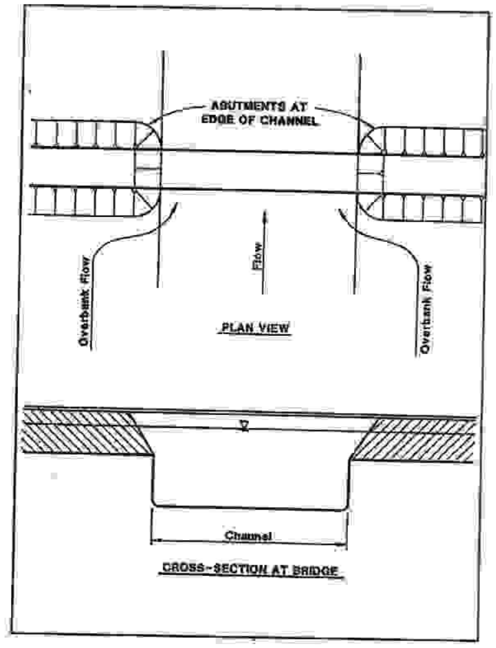
SEDIMENT GRADE SCALE

Size			*Approximate Sieve Mesh Openings (per inch)*		*Class*
Millimeters	Microns	Inches	Tyler	U.S. Standard	
4000-2000	---	180-160	---	---	Very Large Boulders
2000-1000	---	80-40	---	---	Large Boulders
1000-500	---	40-20	---	---	Medium Boulders
500-250	---	20-10	---	---	Small Boulders
250-130	---	10-5	---	---	Large Cobbles
130-64	---	5-2.5	---	---	Small Cobbles
64-32	---	2.5-1.3	---	---	Very Coarse Gravel
32-16	---	1.3-0.6	---	---	Coarse Gravel
16-8	---	0.6-0.3	2.5	---	Medium Gravel
8-4	---	0.3-0.16	5	5	Fine Gravel
4-2	---	0.16-0.08	9	10	Very Fine Gravel
2.00-1.00	2000-1000	---	16	18	Very Coarse Sand
1.00-0.50	1000-500	---	32	35	Coarse Sand
0.50-0.25	500-250	---	60	60	Medium Sand
0.25-0.125	250-125	---	115	120	Fine Sand
0.125-0.062	125-62	---	250	230	Very Fine sand
0.062-0.031	62-31	---			Coarse Silt
0.031-0.016	31-16	---			Medium Silt
0.016-0.008	16-8	---			Fine Silt
0.008-0.004	8-4	---			Very Fine Silt
0.004-0.0020	4-2	---			Coarse Clay
0.0020-0.0010	2-1	---			Medium Clay
0.0010-0.0005	1-0.5	---			Fine Clay
0.0005-0.0002	0.5-0.24	---			Very Fine Clay

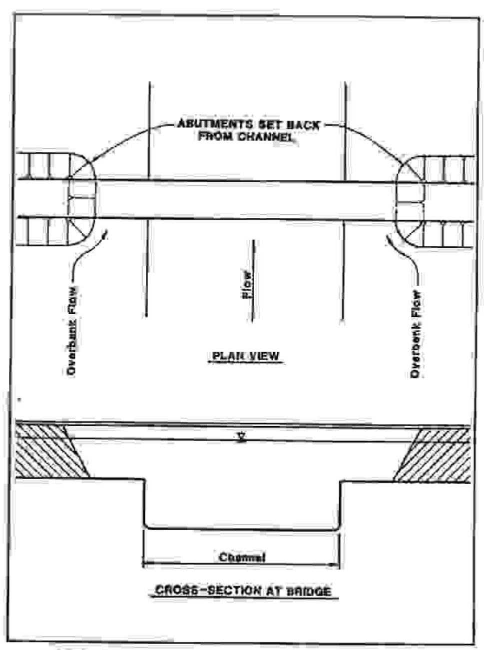
Case 1 Contraction Scour, from Appendix H, "Evaluating Scour at Bridges", Hydraulic Engineering Circular No. 18, Federal Highway Administration, Second Edition, April 1993.



Case 1A: Abutments project into channel

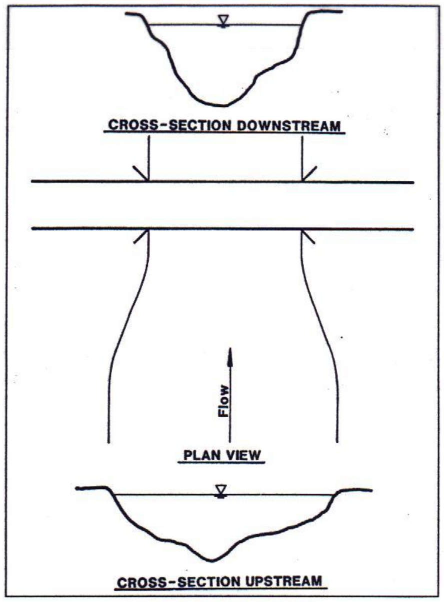


Case 1B: Abutments at edge of channel

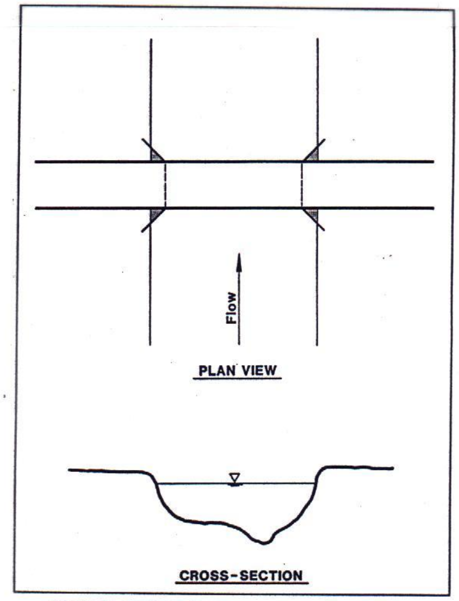


Case 1C: Abutments set back from channel

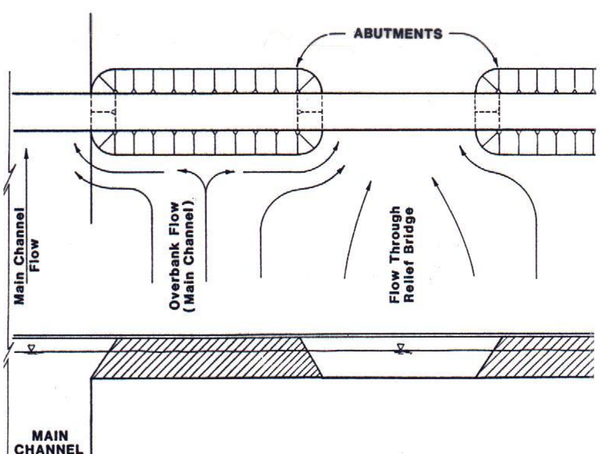
Cases 2, 3 and 4 Contraction Scour, from Appendix H, "Evaluating Scour at Bridges", Hydraulic Engineering Circular No. 18, Federal Highway Administration, Second Edition, April 1993.



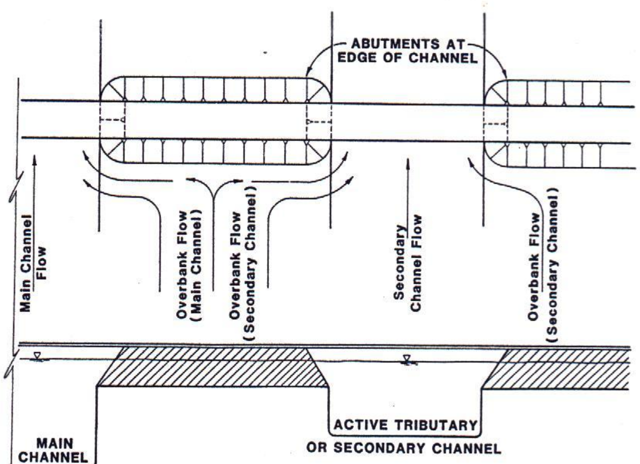
Case 2A: River narrows



Case 2B: Bridge abutments constrict flow



Case 3: Relief bridge over flood plain



Case 4: Relief bridge over secondary stream

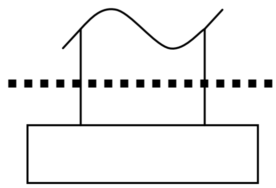
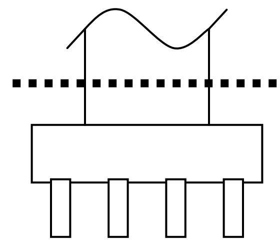
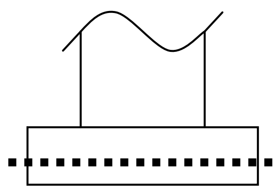
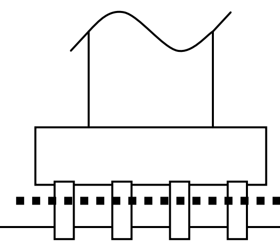
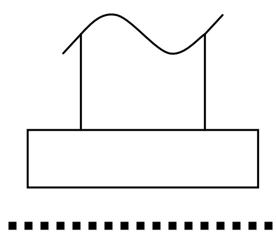
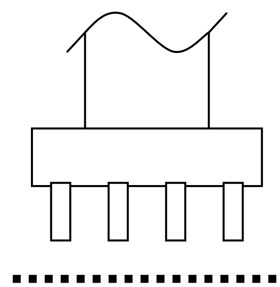
From “Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation’s Bridges”, Federal Highway Administration, December 1995.

ITEM 113--SCOUR CRITICAL BRIDGES

Use a single-digit code as indicated below to identify the current status of the bridge regarding its vulnerability to scour. Scour analyses shall be made by hydraulic/geotechnical/structural engineers. Details on conducting a scour analysis are included in the FHWA Technical Advisory 5140.23 titled, “Evaluating Scour at Bridges”. Whenever a rating factor of 4 or below is determined for this item, the rating factor for “Item 60 – Substructure” may need to be revised to reflect the severity of actual scour and resultant damage to the bridge. A scour critical bridge is one with abutment or pier foundations which are rated as unstable due to (1) observed scour at the bridge site or (2) a scour potential as determined from a scour evaluation study.

Code	Description
N	Bridge not over waterway.
U	Bridge with “unknown” foundation that has not been evaluated for scour. Since risk cannot be determined, flag for monitoring during flood events and, if appropriate, closure.
T	Bridge over “tidal” waters….
9	Bridge foundations (including piles) on dry land well above floodwater elevations.
8	Bridge foundations determined to be stable for assessed or calculated scour conditions; calculated scour is above top of footing. (Example A)
7	Countermeasures have been installed to correct a previously existing problem with scour. Bridge is no longer scour critical
6	Scour calculation/evaluation has not been made. <u>(Use only to describe cases where bridge has not yet been evaluated for scour potential.)</u>
5	Bridge foundations determined to be stable for calculated scour conditions; scour within limits of footing or piles. (Example B)
4	Bridge foundations determined to be stable for calculated scour conditions; field review indicates action is required to protect exposed foundations from effects of additional erosion and corrosion.
3	Bridge is scour critical; bridge foundations determined to be unstable for calculated scour conditions: --Scour within limits of footing or piles. (Example B) --Scour below spread-footing base or pile tips. (Example C)
2	Bridge is scour critical; field review indicates that extensive scour has occurred at bridge foundations. Immediate action is required to provide scour countermeasures.
1	Bridge is scour critical; field review indicates that failure of piers/abutments is imminent. Bridge is closed to traffic.
0	Bridge is scour critical. Bridge has failed and is closed to traffic.

ITEM 113--SCOUR CRITICAL BRIDGES (CONT'D)

Example	**Calculated Scour Depth**		**Action Needed**
	Spread Footing (not founded in rock)	Pile Footing	
A. Above top of footing			None--indicate rating of 8 for this item
B. Within limits of footing or piles			Conduct foundation structural analysis
C. Below pile tips or spread footing base			Provide for monitoring and scour countermeasures as necessary.

Calculated Scour Depth = ▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪

BULLETIN NO. 4

IOWA HIGHWAY RESEARCH BOARD

Scour Around Bridge Piers And Abutments

by

Emmett M. Laursen and Arthur Toch

Iowa Institute of Hydraulic Research

State University of Iowa

Prepared by the

Iowa Institute of Hydraulic Research

in cooperation with

THE IOWA STATE HIGHWAY COMMISSION

and

THE BUREAU OF PUBLIC ROADS

May 1956

PB—C-8314

adapted from Laursen, Bulletin #4

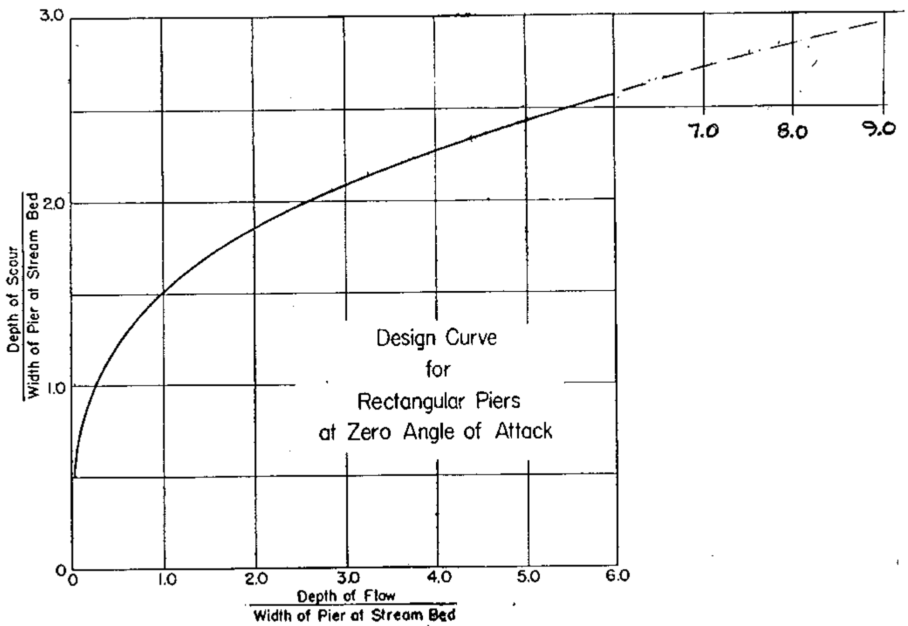


Fig. 38. Basic design curve for depth of scour.

From Laursen Bulletin #4

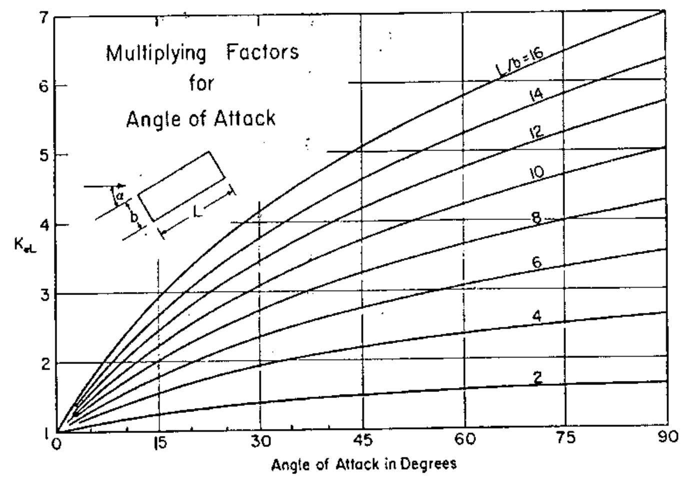


Fig. 39. Design factors for piers not aligned with flow.

TABLE V

Shape coefficients K_s for nose forms

(To be used *only* for piers aligned with flow)

Nose form	Length-width ratio	K_s
Rectangular		1.00
Semicircular		0.90
Elliptic	2:1	0.80
	3:1	0.75
Lenticular	2:1	0.80
	3:1	0.70

C3.2.2.7.1 Types

C3.2.2.7.2 Design conditions

C3.2.2.7.3 Evaluating existing structures

C3.2.2.7.4 Depth estimates

C3.2.2.7.5 Countermeasures

C3.2.2.7.5.1 Riprap at abutments

C3.2.2.7.5.2 Riprap at piers

C3.2.2.7.5.3 Wing dikes

Determining Wing Dike Lengths

The use of wing dikes (also called spur dikes or guide banks) shall be considered at any bridge site that has appreciable overbank discharge. Wing dikes help minimize backwater and scour effects. Refer to IDOT's Office of Design Standard RL-3 for specific details on slopes, dimensions and other notes. Items that need to be specified for RL-3 include Length and Station Location.

Generally, the top of dike elevation will be the same as the abutment berm elevation. However, if this berm elevation is much higher than the Q_{50} or Q_{100} elevations, a lower wing dike elevation may be specified.

The following guidelines provide assistance in determining appropriate wing dike lengths. "Long" and "Short" refer to the longer and shorter wing dikes necessary on skewed bridges as shown on RL-3. If obtaining right of way for the recommended length is a problem at a bridge site, a shortened wing dike is preferred over no dike.

Wing Dike Lengths, in feet (meters)							
Bridge Length, feet (meters)	Bridge Skew						
	0 deg.	15 deg.		30 deg.		45 deg.	
	Equal	Long	Short	Long	Short	Long	Short
< 150 (45)	40 (12)	45 (14)	40 (12)	60 (18)	40 (12)	85 (26)	40 (12)
150-180 (45-55)	50 (16)	60 (19)	50 (16)	80 (24)	50 (16)	120 (36)	50 (16)
180-210 (55-65)	65 (20)	75 (23)	65 (20)	100 (30)	65 (20)	150 (45)	65 (20)
210-240 (65-75)	80 (24)	95 (28)	80 (24)	120 (36)	80 (24)	180 (54)	80 (24)
> 240 (75)	95 (28)	105 (32)	95 (28)	140 (42)	95 (28)	205 (63)	95 (28)

C3.2.2.7.6 Coding

C3.2.3 Highway crossings

C3.2.3.1 Clearances

C3.2.3.2 Ditch drainage

C3.2.4 Railroad crossings

C3.2.4.1 BNSF and UP overhead structures

C3.2.4.1.1 Vertical clearance

C3.2.4.1.2 Horizontal clearance

C3.2.4.1.3 Piers

C3.2.4.1.4 Bridge berms

C3.2.4.1.5 Drainage

C3.2.4.1.6 Barrier rails and fencing

C3.2.4.2 Non-BNSF and -UP overhead structures

C3.2.4.2.1 Vertical clearance

C3.2.4.2.2 Horizontal clearance

C3.2.4.2.3 Piers

C3.2.4.2.4 Bridge berms

C3.2.4.2.5 Drainage

C3.2.4.2.6 Barrier rails and fencing

C3.2.4.3 Underpass structures

C3.2.4.4 Submittals

C3.2.5 Pedestrian and shared use path crossings

C3.2.6 Superstructures

C3.2.6.1 Type and span

C3.2.6.1.1 CCS J-series

C3.2.6.1.2 Single-span PPCB HSI-series

C3.2.6.1.3 Two-span BT-series

C3.2.6.1.4 Three-span PPCB H-series

C3.2.6.1.5 Three-span RSB-series

C3.2.6.1.6 PPCB

Methods Memo No. 159: Policy on Bulb Tee Use
1 June 2008

Preliminary haunch for all Prestressed Beam Bridges

Note: The calculations provide a haunch thickness estimate (X) value, which does not~~n't~~ include the nominal haunch thickness.

$S := 111.5\,ft$ Longest Span (feet)

$e := 0.03$ Superelevation (feet/feet)

$G_1 := -1.68$ Grade 1 vertical curve [+ increasing, - decreasing] (%)

$G_2 := 2.10$ Grade 2 vertical curve [+ increasing, - decreasing] (%)

$$A := \frac{G_2 - G_1}{100} \qquad A = 0.038$$

$L := 984\,ft$ Length vertical curve (feet)

$D_c := 1.75\,deg$ Degree of Horizontal Curvature (degree)

$C := 0.337\,ft$ Final Beam Camber (feet) - From prestressed concrete beam standards

$D := 0.19\,ft$ Dead load deflection - Elastic + 1/2 Plastic (feet) - From prestressed concrete beam standards

$T := 1.667\,ft$ Top flange width (feet)

X = Haunch estimate along the centerline of the beam.

$$X := (C - D) + \frac{S \cdot e}{2} \cdot \left(\frac{1}{\sin\left(\frac{D_c}{2}\right)} - \frac{1}{\tan\left(\frac{D_c}{2}\right)} \right) + \left(\frac{S}{L}\right)^2 \cdot A \cdot \frac{L}{8} \qquad X = 0.219\,ft \qquad X = 66.894\,mm$$

$T \cdot e = 0.6\,in$

If T * e < 1 then X < 4 in. If T * e > 1 then X < 3 in.

Also check maximum offset for horizontal curve < or = 9 in.

C3.2.6.1.7 CWPG

The ~~AASHTO~~ table below extracted from the AASHTO LRFD Specifications [AASHTO-LRFD 2.5.2.6.3] can be used as a guide to establish minimum girder depths, when 1/25 of the span is not possible due to vertical clearance or profile grade issues.

Traditional Minimum Depths for Constant Depth Superstructures

Superstructure		Minimum Depth (Including Deck) When variable depth members are used, values may be adjusted to account for changes in relative stiffness of positive and negative moment sections.	
Material	Type	Simple Spans	Continuous Spans
Steel	Overall Depth of Composite I-Beam	0.040L	0.032L
	Depth of I-Beam Portion of Composite I-Beam	0.033L	0.027L
	Trusses	0.100L	0.100L

C3.2.6.2 Width

C3.2.6.2.1 Highway

C3.2.6.2.2 Sidewalk, separated path, and bicycle lane

Methods Memo No. 11: Sidewalks on Bridges
21 March 2001

C3.2.6.3 Horizontal curve

C3.2.6.3.1 Spiral curve

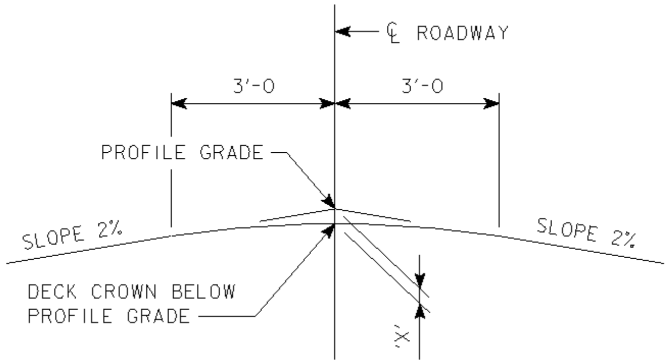
C3.2.6.4 Alignment and profile grade

Methods Memo No. 85: Layout for Bridges on Four Lane Highways
30 January 2004

For situations where the profile grade line is not at the centerline of approach roadway, elevations for the bridge deck will be established taking the bridge deck crown into account. The elevations will be noted on the TS&L as "TOP OF BRIDGE DECK AT CENTERLINE ROADWAY IS 'X' ABOVE (OR BELOW) THE PROFILE GRADE TO ACCOUNT FOR DECK CROSS SLOPE AND PARABOLIC CROWN.

For situations where the profile grade line is at the centerline of approach roadway, elevations for the bridge deck will be established in accordance with Methods Memo No. 222, which is rephrased in BDM 2.5.1.

~~As shown in figure 1, the elevation at the bridge deck crown will be below the roadway profile grade elevation to account for the rounding of the deck with a parabolic template at the cross slope intersection.~~



CROWN TEMPLATE

NO SCALE

~~Figure 1 Recommended Values for `X`~~	
~~Slope %~~	~~X, ft~~
~~2%~~	~~0.03~~
~~2.5%~~	~~0.04~~
~~3%~~	~~0.05~~

~~The rounding of the approach roadway surface is not as well defined as the parabolic template established for the bridge deck crown, however some rounding of the roadway surface at the cross slope intercepts is typical during pavement placement and will match reasonably close to the template shown for the bridge deck crown.~~

~~Using this method will ensure the approach roadway surface in the travelled lanes and the outside edge of pavement, match the bridge deck elevations. Elevations shown on the longitudinal section of the TS&L will reflect the top of bridge deck crown elevations along the centerline of approach roadway to the nearest hundredth of a foot (0.0X). These elevations will be noted on the TS&L as "TOP OF BRIDGE DECK CROWN 'X' BELOW PROFILE GRADE".~~

~~NOTE: The designer shall fill in the `X` value based on the specific project cross slopes. This revision should be made to all projects where detailing has not begun.~~

C3.2.6.5 Cross slope drainage

C3.2.6.6 Deck drainage

Partially revised: Methods Memo No. 81: Deck Drains
24 March 2005

C3.2.6.7 Bridge inspection/maintenance accessibility

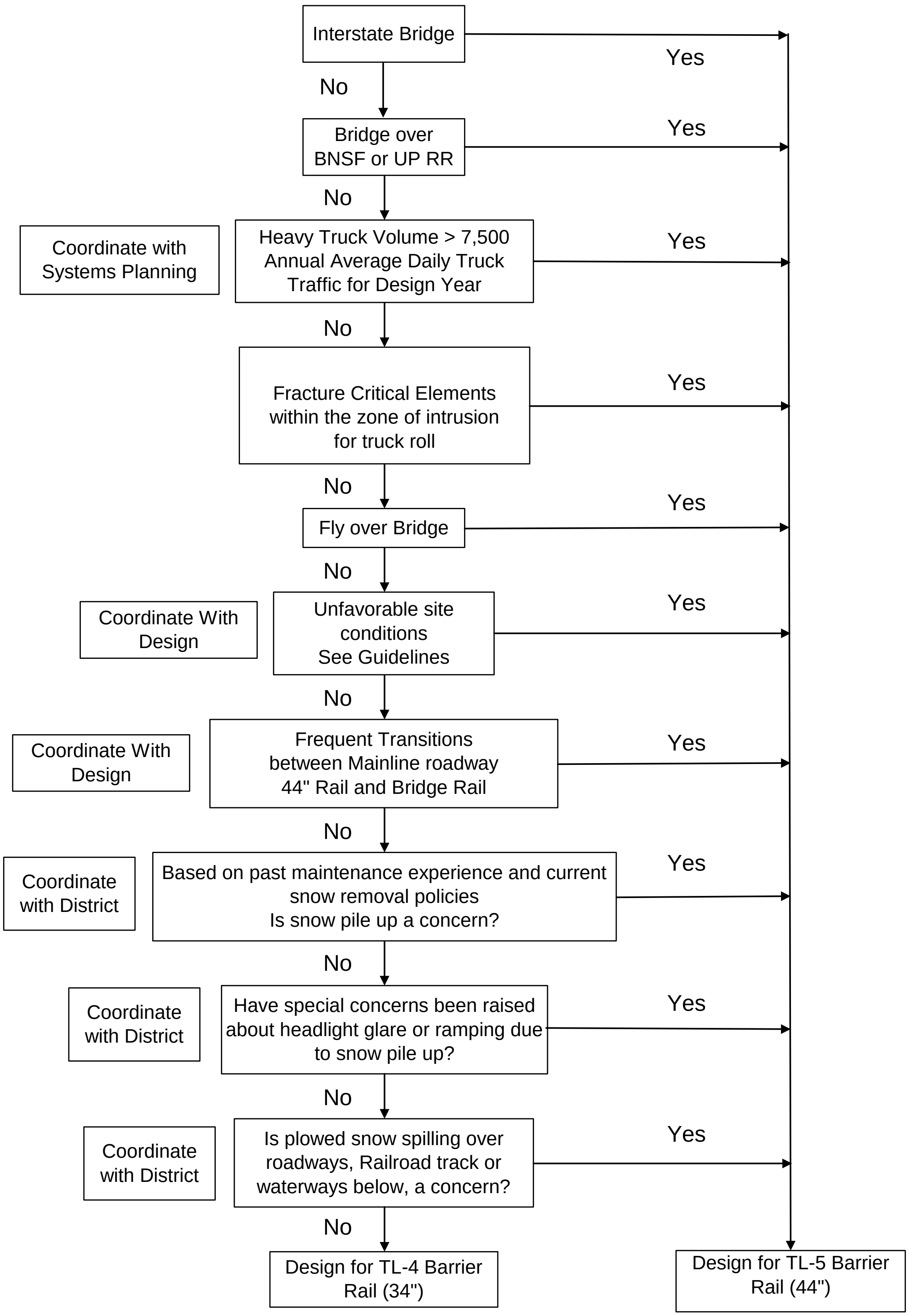
C3.2.6.8 Barrier rails

Partially revised: Methods Memo No. 162: Bridge Railing Selection on Interstate and Primary Highways
29 June 2007

A flow chart is reproduced on the next page [BDM Figure 5.8.1.2.1].

Flow Chart for determining Bridge Barrier Rail Height for New Bridges on Interstate and Primary Highways

Revised 5 May 2009



C3.2.7 Substructures

C3.2.7.1 Skew

C3.2.7.2 Abutments

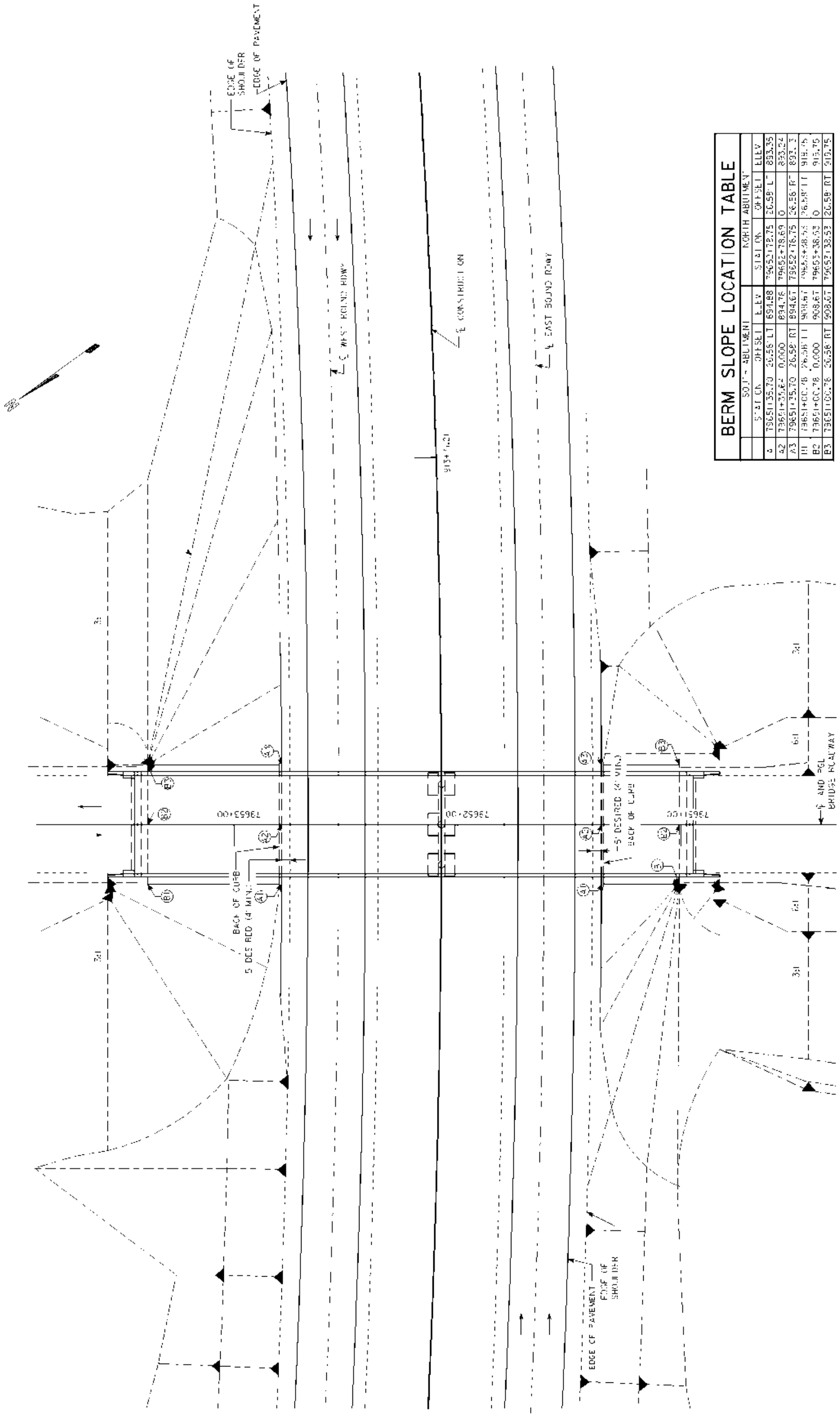
C3.2.7.3 Berms

C3.2.7.3.1 Slope

C3.2.7.3.2 Toe offset

C3.2.7.3.3 Berm slope location table

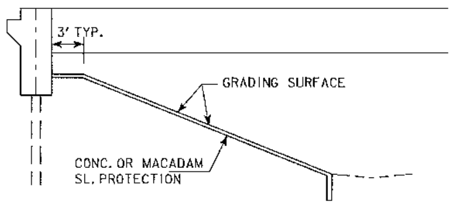
See also the RBLT example C3.2.7.3.4.



BERM SLOPE LOCATION TABLE						
	SOUTH ABUTMENT			NORTH ABUTMENT		
	STATION	OFFSET	ELEV	STATION	OFFSET	ELEV
A1	79651+35.70	26.58' LT	894.88	79652+78.75	26.58' LT	893.35
A2	79651+35.64	0.000	894.76	79652+78.69	0	893.24
A3	79651+35.70	26.58' RT	894.67	79652+78.75	26.58' RT	893.13
B1	79651+00.78	26.58' LT	908.67	79653+38.53	26.58' LT	919.75
B2	79651+00.78	0.000	908.67	79653+38.53	0	919.75
B3	79651+00.78	26.58' RT	908.67	79653+38.53	26.58' RT	919.75

EXAMPLE RL-17 BERM SLOPE LOCATION TABLE

GUIDELINES FOR DESIGNATION OF GRADING SURFACE FOR BSLT



NOTES:

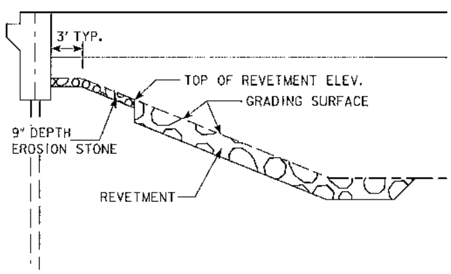
1. BSLT POINTS GIVEN AT THE GRADING SURFACE = TOP OF SLOPE PROTECTION.

2. THE GRADING SURFACE IS DEFINED BY THE BRIDGE OFFICE SLOPE PROTECTION STANDARD.

3. WING ARMORING DETAILS ARE DEFINED BY THE BRIDGE OFFICE WING ARMORING STANDARDS.

4. SLOPE PROTECTION AND WING ARMORING QUANITIES WILL BE CALCULATED IN FINAL DESIGN.

CONCETE OR MACADAM SLOPE PROTECTION



NOTES:

1. BSLT POINTS GIVEN AT GRADING SURFACE = TOP OF EROSION STONE AND TOP OF EMBEDDED REVETMENT.

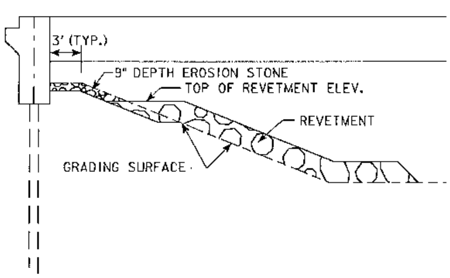
2. THE GRADING SURFACE SHALL BE LABELED ON THE TSL REVETMENT TYPICAL SECTION. TOP OF REVETMENT ELEVATION SHALL BE DEFINED.

3. ADDITIONAL EROSION STONE DETAILS ARE COVERED BY THE BRIDGE OFFICE SLOPE PROTECTION STANDARD.

4. REVETMENT AND EROSION STONE BERM ARMORING ARE PLACED BELOW THE GRADING SURFACE AND WILL REQUIRE "CORE OUT". DEFINE LIMITS OF THE CORE OUT IN THE PLANS. THE BERM ARMORING QUANTITIES TABLE SHALL INCLUDE (AS APPLICABLE) CLASS 10 EXCAVATION, ENGINEERING FABRIC, EROSION STONE AND REVETMENT. BERM ARMORING GENERALLY INCLUDES QUANTITIES TO THE FACE OF THE ABUTMENT.

5. WING ARMORING DETAILS ARE DEFINED BY THE BRIDGE OFFICE WING ARMORING STANDARD. FINAL DESIGN WILL CALCULATE QUANTITIES RELATED TO THE WING ARMORING.

EMBEDDED REVETMENT



NOTES:

1. BSLT POINTS GIVEN AT GRADING SURFACE = TOP OF EROSION STONE AND BASE OF NON-EMBEDDED REVETMENT.

2. THE GRADING SURFACE SHALL BE LABELED ON THE TSL REVETMENT TYPICAL SECTION. TOP OF REVETMENT ELEVATION SHALL BE DEFINED.

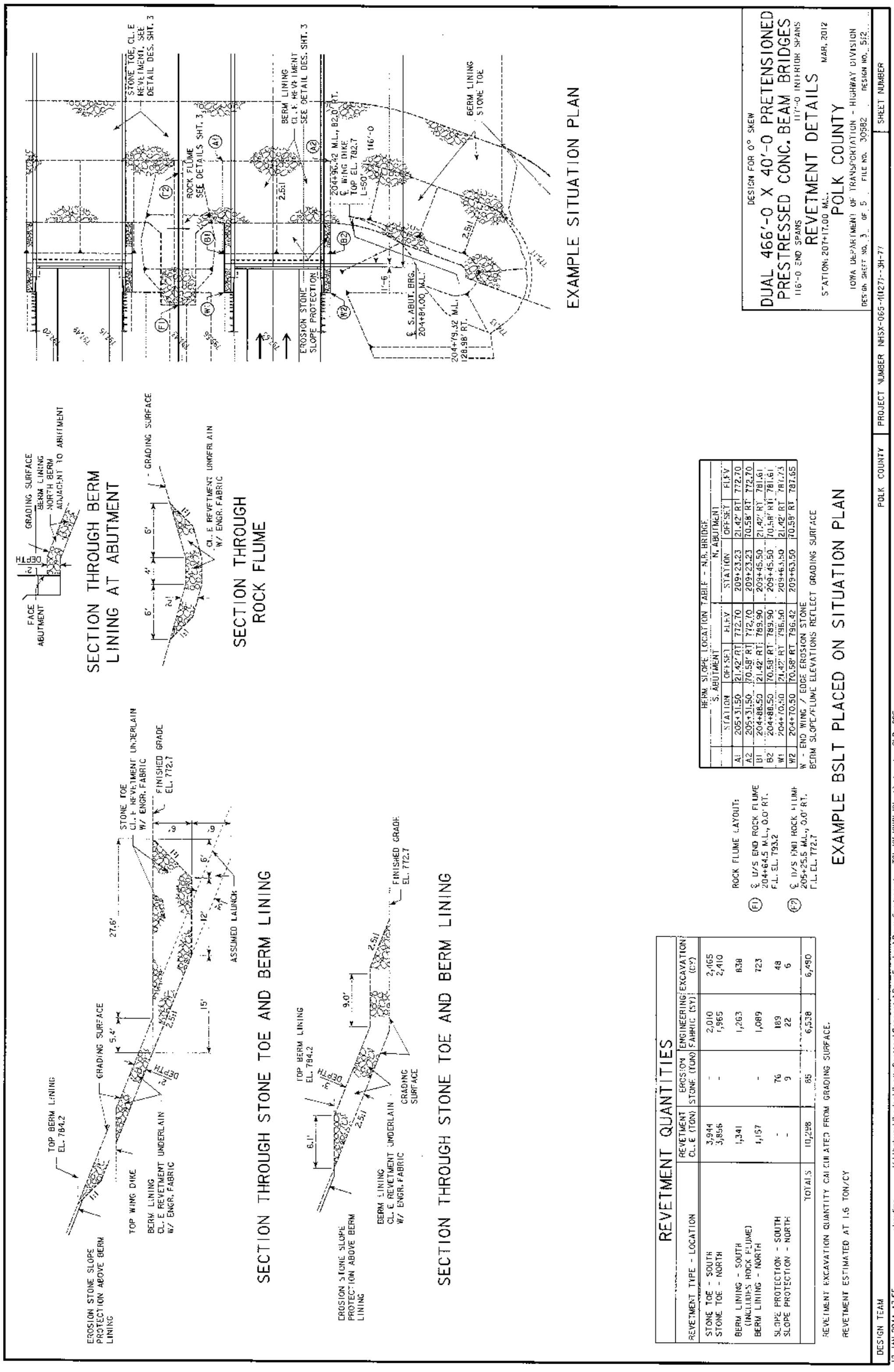
3. ADDITIONAL EROSION STONE DETAILS ARE COVERED BY THE BRIDGE OFFICE SLOPE PROTECTION STANDARD.

4. EROSION STONE IS PLACED BELOW THE GRADING SURFACE AND WILL REQUIRE "CORE OUT". DEFINE LIMITS OF THE CORE OUT IN THE PLANS. THE BERM ARMORING QUANTITIES TABLE SHALL INCLUDE CLASS 10 EXCAVATION, ENGINEERING FABRIC, EROSION STONE, REVETMENT AND CORE OUT. BERM ARMORING QUANTITIES GENERALLY WILL INCLUDE ARMORING WORK UP TO THE FACE OF ABUTMENT.

5. WING ARMORING DETAILS ARE DEFINED BY THE BRIDGE OFFICE WING ARMORING STANDARD. FINAL DESIGN WILL CALCULATE QUANTITIES RELATED TO THE WING ARMORING.

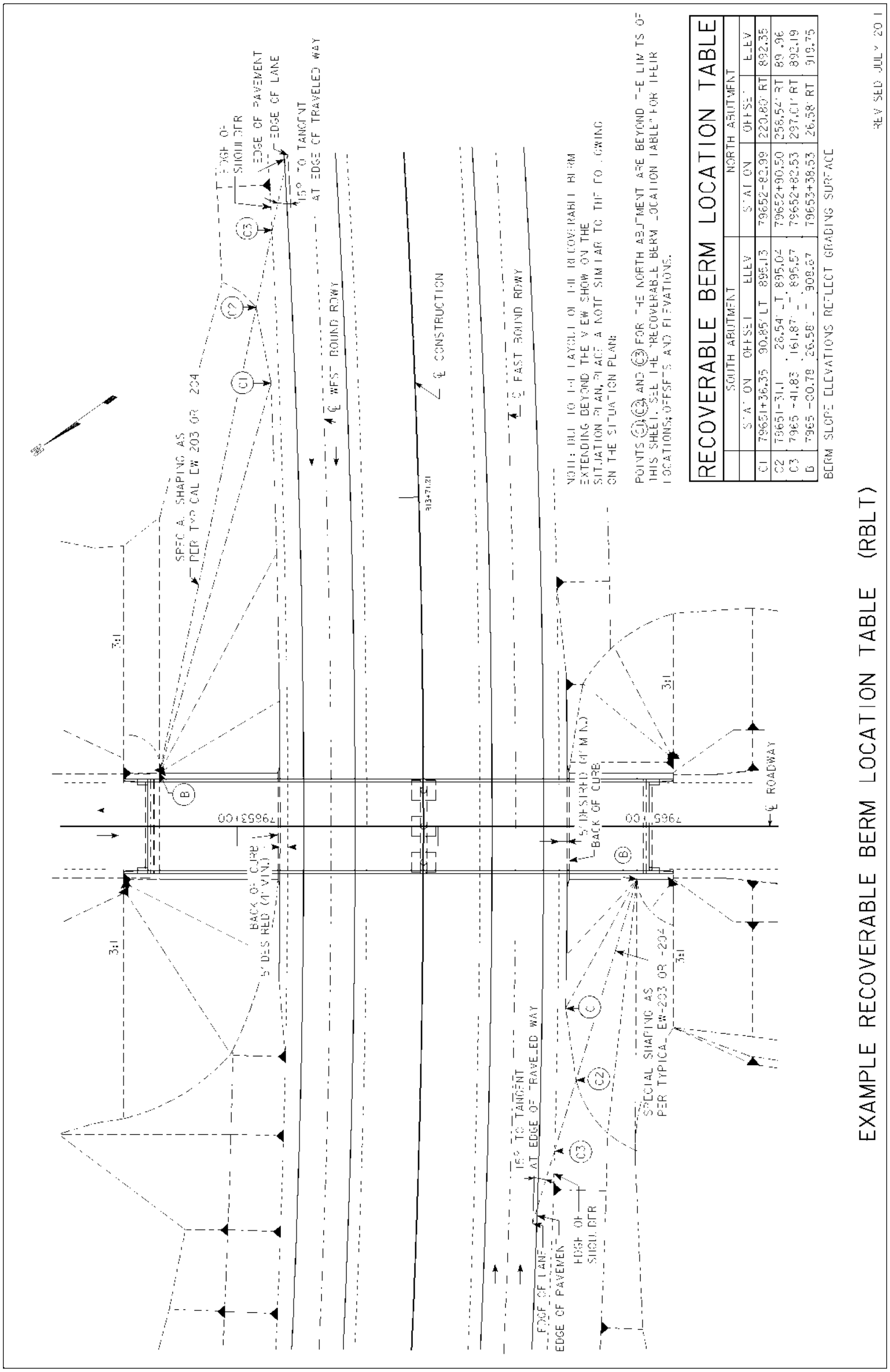
REVETMENT (NOT EMBEDDED)

5-26-11


SECTION THROUGH STONE TOE AND BERM LINING
SECTION THROUGH STONE TOE AND BERM LINING
SECTION THROUGH BERM LINING AT ABUTMENT
SECTION THROUGH ROCK FLUME
EXAMPLE SITUATION PLAN
REVETMENT QUANTITIES
REVETMENT EXCAVATION QUANTITY CALCULATED FROM GRADING SURFACE.
REVETMENT ESTIMATED AT 1.6 TON/CY
BERM SLOPE LOCATION TABLE - N.B. BRIDGE
EXAMPLE BSLT PLACED ON SITUATION PLAN
DESIGN FOR 0° SKEW
DUAL 466'-0 X 40'-0 PRETENSIONED PRESTRESSED CONC. BEAM BRIDGES
REVETMENT DETAILS
POLK COUNTY
IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION

C3.2.7.3.4 Recoverable berm location table

See also the BSLT example in C3.2.7.3.3.



	SOUTH ABUTMENT			NORTH ABUTMENT		
	STATION	OFFSET	ELEV	STATION	OFFSET	ELEV
C1	79651+36.35	90.85' LT	895.13	79652-82.99	220.80' RT	892.35
C2	79651-31.1	26.54' LT	895.04	79652+90.50	256.54' RT	89 .96
C3	7965 -41.83	161.87' LT	895.57	79652+82.53	297.01' RT	892.19
B	7965 -00.78	26.58' LT	908.67	79653+38.53	26.58' RT	919.75

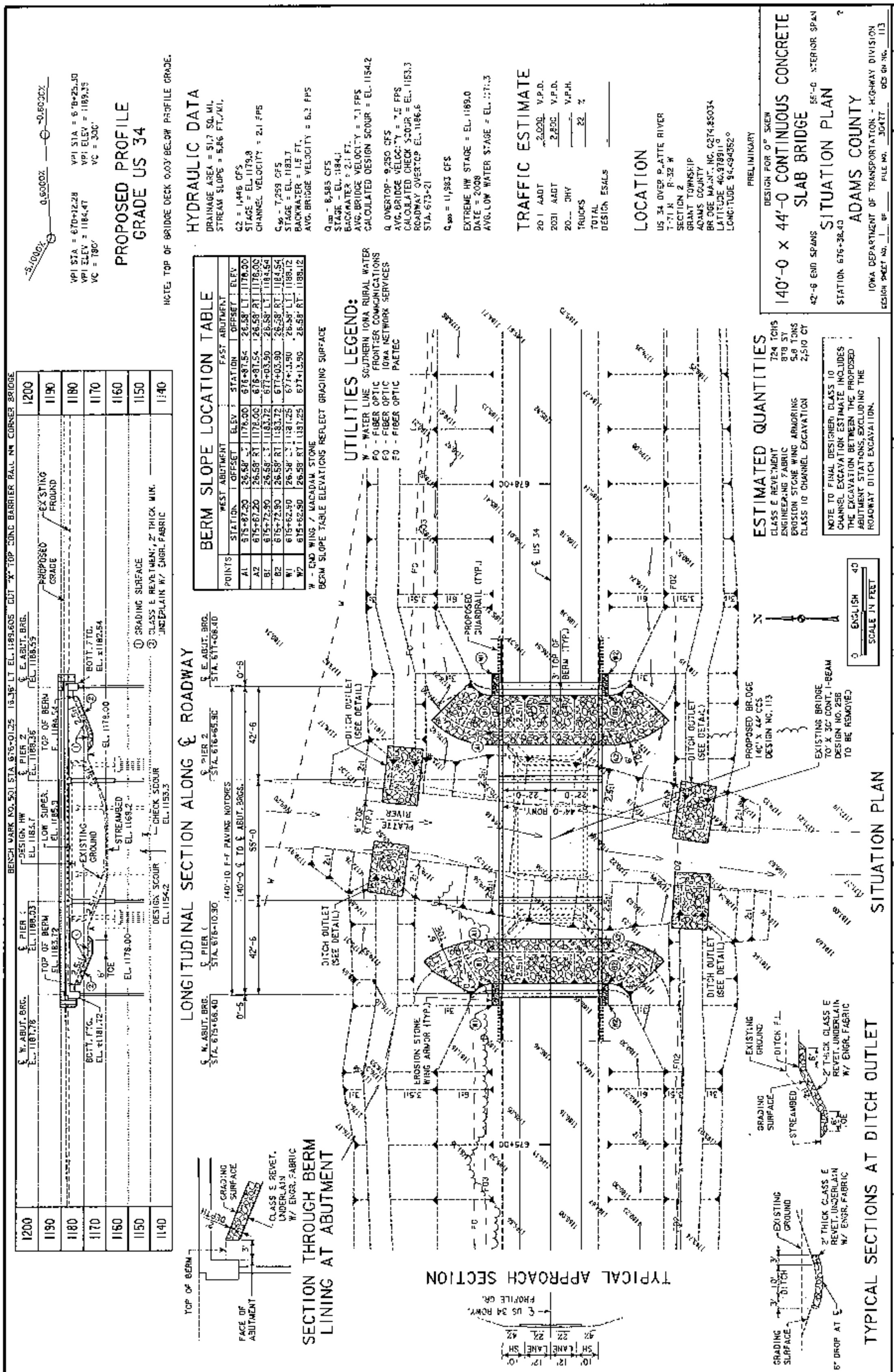
EXAMPLE RECOVERABLE BERM LOCATION TABLE (RBLT)

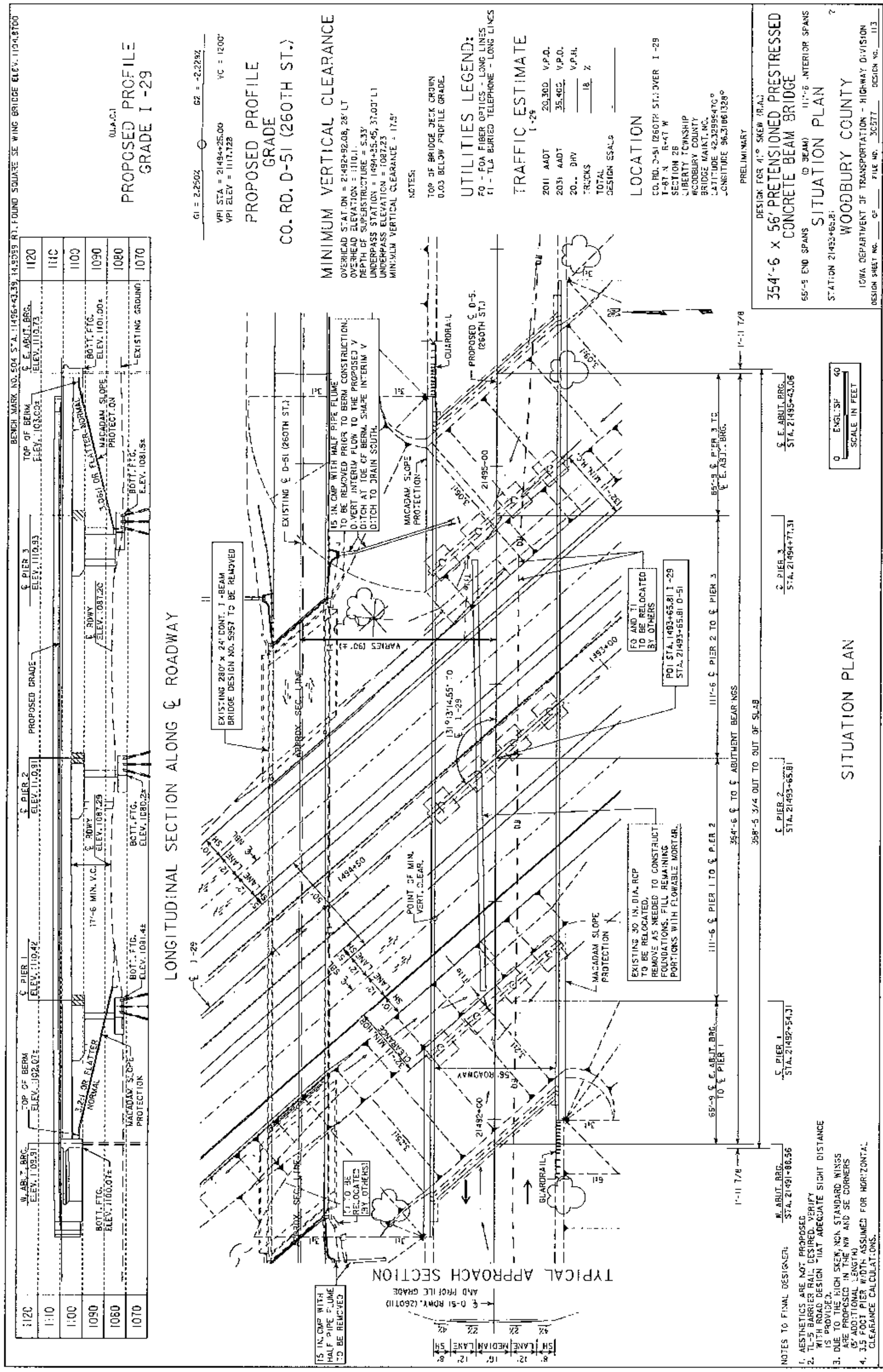
C3.2.7.3.5 Slope protection

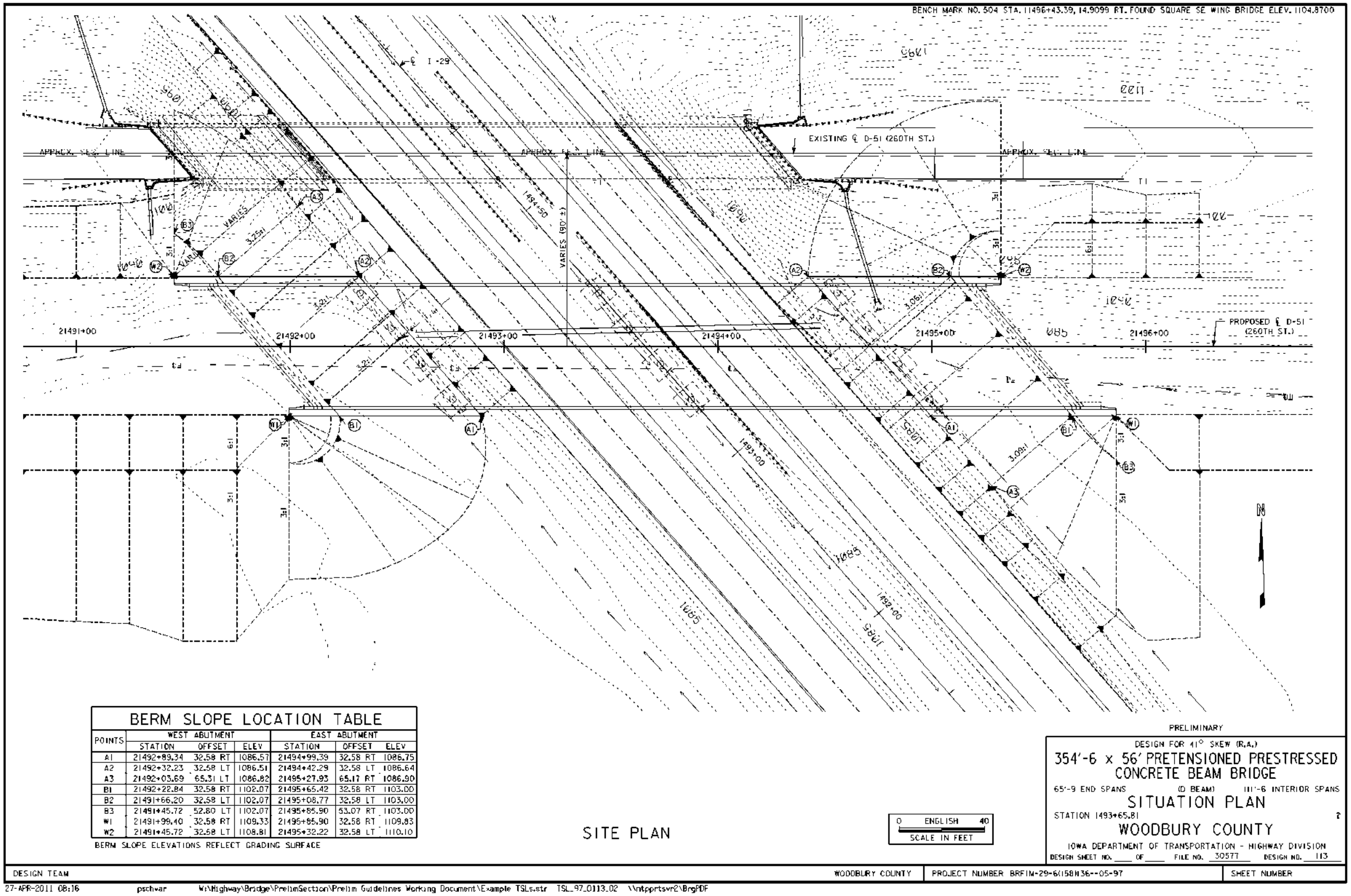
C3.2.7.4 Piers and pier footings

C3.2.8 Cost estimates

C3.2.9 Preliminary situation plans


LONGITUDINAL SECTION ALONG ℄ ROADWAY
SECTION THROUGH BERM LINING AT ABUTMENT
TYPICAL APPROACH SECTION
TYPICAL SECTIONS AT DITCH OUTLET
SITUATION PLAN
BERM SLOPE LOCATION TABLE
UTILITIES LEGEND:
ESTIMATED QUANTITIES
PROPOSED PROFILE GRADE US 34
HYDRAULIC DATA
TRAFFIC ESTIMATE
LOCATION
140'-0 x 44'-0 CONTINUOUS CONCRETE SLAB BRIDGE
SITUATION PLAN
ADAMS COUNTY


LONGITUDINAL SECTION ALONG ℄ ROADWAY
SITUATION PLAN
TYPICAL APPROACH SECTION
PROPOSED PROFILE GRADE I-29
MINIMUM VERTICAL CLEARANCE
UTILITIES LEGEND:
TRAFFIC ESTIMATE
LOCATION
354'-6 x 56' PRETENSIONED PRESTRESSED CONCRETE BEAM BRIDGE
SITUATION PLAN
WOODBURY COUNTY



BERM SLOPE LOCATION TABLE

POINTS	WEST ABUTMENT			EAST ABUTMENT		
	STATION	OFFSET	ELEV	STATION	OFFSET	ELEV
A1	21492+89.34	32.58 RT	1086.57	21494+99.39	32.58 RT	1086.75
A2	21492+32.23	32.58 LT	1086.51	21494+42.29	32.58 LT	1086.64
A3	21492+03.69	65.31 LT	1086.82	21495+27.93	65.17 RT	1086.90
B1	21492+22.84	32.58 RT	1102.07	21495+65.42	32.58 RT	1103.00
B2	21491+66.20	32.58 LT	1102.07	21495+08.77	32.58 LT	1103.00
B3	21491+45.72	52.80 LT	1102.07	21495+85.90	53.07 RT	1103.00
W1	21491+99.40	32.58 RT	1109.33	21495+85.90	32.58 RT	1109.83
W2	21491+45.72	32.58 LT	1108.81	21495+32.22	32.58 LT	1110.10

BERM SLOPE ELEVATIONS REFLECT GRADING SURFACE

C3.2.10 Permits and approvals

C3.2.10.1 Waterway

Department of Natural Resources List of Meandered Streams
22 December 2006

Iowa Department of Natural Resources Sovereign Lands Construction Permits are required for work on or over meandered streams. (This is a different permit than a Floodplain Development Permit.) The term "meandered stream" for this permit is a legal description where the State of Iowa owns the stream bed and banks of certain reaches of rivers. A meandered stream is one which at the time of the original government survey was so surveyed as to mark, plat and compute acreage of adjacent fractional sections. DNR is responsible for this state-owned land and therefore issues a Construction Permit. The following is a list of the descriptions of the limits of these rivers in the state of Iowa.

1. Des Moines River. From Mississippi River to the junction of the east and west branches. The west branch to west line T95N, R32W, Palo Alto County, due south of Emmetsburg. The east branch to north line T95N, R29W, Kossuth County, near the north edge of Algona.

2. Iowa River. From Mississippi River to west line T81N, R11W, Iowa County, due north of Ladora.

3. Cedar River. From Iowa River to west line T89N, R13W, Black Hawk County, at the east edge of Cedar Falls.

4. Raccoon River. From Des Moines River to west line of Polk County.

5. Wapsipinicon River. From Mississippi River to west line T86N, R6W, Linn County northwest of Central City.

6. Maquoketa River. From Mississippi River to west line T84N, R3E Jackson County, due north of Maquoketa.

7. Skunk River. From Mississippi River to north line of Jefferson County, at the southwest edge of Coppock.

8. Turkey River. From Mississippi River to west line T95N, R7W, Fayette County, northwest of Clermont.

9. Nishnabotna River. From Missouri River to north line T67N, R42W, Fremont County, northeast of Hamburg.

10. Upper Iowa River. From Mississippi River to west line Section 28, T100N, R4W, Allamakee County, about two and one-half miles upstream from its mouth.

11. Little Maquoketa River. From Mississippi River to west line Section 35, T90N, R2E, Dubuque County, about one mile upstream from its mouth.

12. Mississippi River, Missouri River, Big Sioux River.

C3.2.10.2 Railroad

C3.2.10.3 Highway

C3.2.11 Forms

Examples of forms to follow:

Bridge Cost Estimate for Concept Statement

Location:

County: Lucas	Proj. No.: BRF-014-2(34)--38-59
Des. No.: 1054	Pin No.: 09-59-014-010
Maint. No.: 5927.3S014	FHWA No.: 34460
On IA 14 over English Creek	Sta.: 502+19.1
Section 13,T73N,R21W	
Functional Class:	ADT: 2580 vpd
By: D. Claman	Date: 5/17/2010

Existing Bridge:

Type: I-Beam	Length x Width: 60' x 30'
Pier Type: N/A	Abut. Type: Stub
Spans: 60	Approach Pavement Width: 30
Skew: 0	Design Loading:

Drainage Area: 7.8 sq. mi.
Existing Bridge Width Acceptable: No
New/Reconstructed Roadway Width: 44.0'
Repair/Remodel by Staging Traffic: Yes

General Comments: Existing bridge is a 4-beam single span structure that could be staged. Stage 1 lane width would be 15' wide and Stage 2 lane width would be approximately 12 feet wide with an additional 2' wide bridge. Staging a slab bridge may create constructability issues due to deflection and false-work.

Option A - Stage 110' x 46' CCS Bridge

Type: CCS	Length x Width: 110' x 46'
Pier Type: Pile Bent	Abutment Type: Integral
Spans: 1 @ 35', 2@27.5'	Skew: 0.0

Stage Traffic: Yes, One 15' Lane - Stage 1, One 12' Lane - Stage 2
Costs:

Bridge - 110' x 46' @ $75/sf	= $ 379,500
Remove Exist. Bridge -60' x 30' @ $7.00/sf	= $ 12,600
Riprap Berms	= $ 50,000
Staged Construction (10%)	= $ 44,210
Mobilization (10%)	= $ 44,210
Contingency (15%)	= $ 66,315
	========
Total Option A	$ 596,835

Comments: Staged CCS bridges may have constructability issues depending upon the contractor.

Page 1 of 2

Bridge Concept Statement 4/12/2011

Lucas County
BRF-014-2(34)—38-59

Option B - 110' x 44' CCS Bridge - Detour

Type: CCS	Length x Width: 110' x 44'
Pier Type: Pile Bent	Abutment Type: Integral
Spans: 1@35.0, 2@ 27.5'	Skew: 0.0
Stage Traffic: No	

Costs:

Bridge - 110' x 44' @ $75/sf	= $ 363,000
Remove Exist. Bridge 60' x 30' @ $7.00/sf	= $ 12,600
Riprap Berms	= $ 50,000
Mobilization (10%)	= $ 42,560
Contingency (15%)	= $ 63,840
	========
Total Option B	$ 532,000

Comments: Detour reduces construction time and eliminates constructability issues staging slab bridges.

Revisions:

None

Iowa Department of Transportation
Form 532001wd 11-2003

RECORD OF COORDINATION
FLOODPLAIN DEVELOPMENT

The purpose of this form is to document Iowa Department of Transportation coordination with the local community for projects which are not within the Iowa Department of Natural Resources' permitting jurisdiction and which are in a community that is participating in the National Flood Insurance Program.

1. Highway Number: ____________ Stream ______________________ Project Number ____________________

   File No.: ________ Design No. _______ Project Location: ______ ¼, ______ ¼, T ______ ,S ______ ,R ______

   Description of Location: ____

   ____

   City/County: ____

2. Flood Insurance Rate Map/Floodway Map:

   Panel Number: ______________________________ , Effective Date of Map: ______________

3. Type of Development: ☐ Filling ☐ Grading ☐ Excavation ☐ Bridge Construction ☐ Road Construction

   Channel Improvement: ____

   Description of Development: ____

   ____

4. Is project located in a designated 100-year floodplain?

   ☐ Yes (check the appropriate zone: ☐ A ☐ A1-30 ☐ AE ☐ AO ☐ AH) ☐ No

5. Has a detailed Flood Insurance Study (FIS) been published? ☐ Yes ☐ No

   If yes, what is the Base Flood Elevation (BFE) at project site? ______________________

   If no, what is the estimated BFE at project site? ______________________

6. Is project located in designated floodway? ☐ Yes ☐ No

7. Does FIS need to be revised? ☐ Yes ☐ No

   If yes, describe type and extent of revision: ______________________________

   ____

IDOT Preliminary Bridge Design Engineer	Signature	Date
IDOT District Engineer	Signature	Date

Community Official Concurrence:

Community Official	Signature	Date

NOTE: Office of Bridges and Structures to submit copy to:
Bill Cappuccio
NFIP State Coordinator
Iowa Department of Natural Resources
Wallace State Office Building
502 East Ninth Street
Des Moines, IA 50319
515-281-8942

Form 621004wd
06-95

Iowa Department of Transportation

EXAMPLE

FIELD NOTES FOR BRIDGES AND LARGE CULVERTS (20' SPAN)
PRIMARY ROAD SYSTEM

LOCATION

1. County Boone Civil Twp. Worth Sec. 21 Twp. 83N Range 26W
2. Over (☐River, ☒Cr., ☐Dr. Ditch) Peese Creek Highway No. Oriole Road
3. Proj. No. ER-624-0(8)--28-08 Sta. Pres. Struct. 8+28.00 Aerial Map No. ____
   Sta. Prop. Struct. 8+28.00

GENERAL DATA (FIELD)

4. Drainage Area 8.75 sq-mi Character Hilly to flat Approx. length and width 4.8 mi. x 2.8 mi
5. Extreme highwater: Date of occurrence 1993 Information from Ledges State Park Flood Pole
   (Elev. near site 892.5 Location STA 6+47.21, RT 152.27') (Elev. Upstream ____
   Location ____) (Elev. downstream ____ Location ____)
6. Typical highwater: Elev. 863.5 Occurs every 2 Years. Date of last occurrence Unknown
7. Average low water: (Elev. at site 862.47 Average streambed 862.27) (Water elev. 862.47 on date of survey 12/10/2010)
   (Water elev. 865.52 upstream 582 Ft.) (Water elev. 858.31 downstream 494 Ft.) Fall in stream 35.38 Ft./mi.
8. List buildings in flood plain None Location ____ Floor Elev. ____
9. Upstream Land Use State Park Anticipate any Change? No
10. Is stream deepening or filling? Filling Approx. amount per year Unknown
11. Is stream widening? No Show direction, rate and amount)
12. Does stream carry appreciable amount of ice? No Elev. Of high ice ____
13. Does stream carry appreciable amount of large driftwood? Yes
14. Bench Mark No. BM503 RR Spike in West Face of Flood Pole Northwest of G001 STA 6+47.21, RT. 152.27'

PRESENT OR OLD STRUCTURE

15. Superstructure: Type Dual 20.5' x 7.25' Aluminum Box Culvert Skew angle 27.42° L.A.
16. Substructure: Type N/A
17. Span lengths N/A Roadway width 22' Type of floor N/A
18. Culvert: Span 20.5' Ht. 7.25' Length B-B Ppts. 59' Flowline Lt. 859.0 Rt. 859.0
19. Grade elev. 868.0 Date built 2000 IDOT Design No. SP-624-0(5)--7C-06
20. Condition of superstructure Damaged beyond repair
21. Condition of substructure ____
22. Remarks: Existing dual culverts damaged beyond repair from August 2010 flood.

PROPOSED STRUCTURE (OFFICE)

23. Superstructure: Type 120' x 30' Continuous Concrete Slab Bridge Skew angle 30° L.A.
24. Substructure: Type P10L, Integral Abutments
25. Span lengths (Bridge): 36.5', 47.0',36.5' Culvert B-B Ppts. ____
26. Culvert: Span ____ Ht. ____ Flowline Lt. ____ Rt. ____ Length Lt. ____ Rt. ____
27. Roadway width 30' Type of floor Concrete Class of loading HL-93
28. Type of railing TL-4, Open Rail Option Type of curb ____
29. Grade elev. 871.96 Abut. Footing elev. 865.66 Pier footing elev. 858.25
30. Length and type of pilings: Abuts. HP10x42 - 45' Piers HP10x42 - 50' (P1), 55' (P2)
31. Design highwater: Elev. 867.00 Frequency 50 Year Area 8.75 sq-mi Discharge 2,272 cfs
32. What provision is made for overflow? None
33. Can channel be cleared to provide more waterway? No Are wing dikes to be provided? No
34. Is excessive local scour probable? No Probable max. depth of scour below streambed 4.40 ft.
35. Disposition of existing structure Remove
36. 2007 ADT = 530 VPD
37. Remarks: ____

County Boone
Project. No. ER-624-0(8)--28-08
File No. 30586 PIN 11-08-624-010
Design No. 211 Maint. No. 0800.3S624

Field Notes by Adam Bullerman, P.E. Date 2-25-11

Title Project Engineer

(over)

EXAMPLE

VALLEY CROSS SECTION DATA

The submittal of a bridge type structure will include a right angle valley section. This section should be taken downstream from the crossing. It shall be noted whether it is an average section or a control section. Enough ground shots will be taken to outline the valley to an elevation well above extreme highwater. Special care will be taken to accurately outline the main channel. Each shot should be identified; that is (FP) flood plain, (TB) top of bank, (ES) edge of stream, etc. Mannings equation roughness factors will be assigned each shot. Include site photos with this information.

Remarks: Refer to HEC-RAS model for valley cross section data

Distance	Elevation	(N) Roughness	Remarks

Distance	Elevation	(N) Roughness	Remarks

PLAT OF DRAINAGE AREA

The drainage area is to be platted as completely and accurately as possible and to the largest practicable scale on a separate sheet. Use a definite scale, as 1" equals ¼, ½, 1 or 2 miles, and indicate what scale has been used. In addition to the outlines of the watershed, indicate the positions of the streams and, roughly, the character of the soil and the relative locations of the steep and flat portions. Whenever practicable, the above information should be secured by going over the area either on foot or in a car. For most watersheds the information may be secured from the best existing data, soil maps, U.S.G.S. maps and Bulletin No. 7-1.H.R.B. No plat is necessary if the area is listed in Bulletin Number 7.

Remarks:

Give additional information by reference to marginal number on reverse side of this sheet.

Marginal No.	
5	Extreme highwater due to backwater from Saylorville Lake
10	Excessive silt deposition at this site is due to backwater from Saylorville Lake
18	Culvert flowline data based on construction plans since flow-line data could not be obtained due to culvert damage

IMPORTANT NOTE

The information given on this form must in all cases be supplemented by complete plat and profile of the site, drawn to a convenient scale on a separate sheet.

The information as shown on this form is essential and must be supplied in detail before the plans can be prepared or approved. It will be necessary to return this form for correction unless the data supplied is complete.

Instructions for Completing Risk Assessment Form for Bridges (Culverts) Over Waterways

This form needs to be completed only for those river bridges needing FHWA approval.

Hydrologic Evaluation

A. Check USGS Water Resources Data
B. Check Flood Insurance Studies, USGS reports, Corps of Engineer projects, etc.
C. Estimate backwater for each. (Method used is optional.) The backwater estimates should be based on the recommended structure. Method used to compute discharge is normally USGS Report 87-4132 or gaging station data if a gaging station is near the site.
D. For example, DNR Floodplain Development Permit, or Corps 404 Permit.

Property Related Evaluation

A. Low damage potential - No buildings.
Moderate damage potential - Outbuildings.
High damage potential - Residential/industrial.
B. For Flood Insurance Studies, all the information should be in the study. Call DNR for additional information.

Environmental Considerations

A. Check the Concept Statement or the Environmental Assessment.

Highway and Bridge (Culvert) Related Evaluation

A. Check appropriate features if any.
B. Identify recurrence interval at overtopping (proposed roadgrade) if less than 500 year.
Length of overtopping ______ m at Q_{50}.

Miscellaneous Comments

A - E. Self Explanatory.
F. Sample comments:
Bank stabilization may be required in the future - not recommended at this time.
Riprap on spur dikes not recommended on this project.

Traffic Related Evaluations

A. Self explanatory.
B. Self explanatory.
C. Self explanatory.
D. Detour - If the road (structure) washed, what is the length of the posted detour route?

Present Facility

A. Self explanatory.
B. At what discharge and recurrence interval does the existing road overtop.
C. Self explanatory. Most streams draining less than 1300 sq. kilometers are subject to flash flooding.

Alternates

A. Self explanatory.
B. Self explanatory.
Discussion: If other alternatives were considered (e.g., longer bridge or shorter bridge or culvert), state in a general way and give reason for rejection.

Examples: A culvert was considered but was rejected because of drift potential.
A longer bridge was considered but was not necessary hydraulically and was too costly.

C. For most sites, further analysis would not be necessary.

Form 517002wd
11-02

Iowa Department of Transportation

RISK ASSESSMENT FOR BRIDGES (CULVERTS)
(For 20' Span and Longer Structures)

EXAMPLE

LOCATION

County Boone Civil Twp. Worth Sec. 21 Twp. 83N Range 26W

Over (River, Cr., Dr. Ditch) Peese Creek Road No. Oriole Road

Project No. ER-624-0(8)--28-08 Design Number 211 FHWA No. 699111

Assessment Prepared by Adam Bullerman, P.E. Date 2/25/11

1. HYDROLOGIC EVALUATION

A. Nearest Gaging Station available on this stream: ____ (None ☒)

B. Are flood studies available on this stream: Yes ☐ No ☒

C. Flood Data:

Q_{10} N/A cfs Est. Bkwtr. N/A ft. Q_{25} N/A cfs Est. Bkwtr. N/A ft.

Q_{50} 2,272 cfs Est. Bkwtr. -0.64 ft. Q_{100} 2,760 cfs Est. Bkwtr. -0.53 ft.

Q_{500} 3,646 cfs or Overtopping ____ cfs (Whichever is lower)

Drainage Area 8.75 sq-mi Method Used to compute Q WRIR 87-4132 w/ Mixed Landforms

D. Does the crossing require outside agency approval? Yes ☒ No ☐

List Agencies: Iowa DNR Sovereign Lands

2. PROPERTY RELATED EVALUATIONS

A. Damage potential: Low ☐ Moderate ☒ High ☐

List buildings in flood plain None Location ____

Floor Elevation ____

Upstream Land Use ____

Anticipate any Change? Yes ☐ No ☒

If yes, describe anticipated change: ____

B. Any flood zoning? (Flood Insurance Studies (FIS), etc.) Yes ☒ No ☐

Type of Study Approximate

Base flood elevation None, Zone A (100 year)

Regulatory floodway width None (As noted in FIS Studies)

Comments Boone County is currently mapped but this area has a Zone A Special Flood Hazard Area designation

3. ENVIRONMENTAL CONSIDERATIONS

A. List commitments in environmental documents which affect hydraulic design (None ☒)

4. HIGHWAY AND BRIDGE (CULVERT) RELATED EVALUATIONS

A. Note any outside features which might affect Stage, Discharge, or Frequency.

Levees ☐ Aggradation / Degradation ☐ Reservoirs ☐ Diversions ☐

Drainage Dist. ☐ Navigation ☐ Backwater from another source ☒

Other ____

Explanation Project is located in the flood pool of Saylorville Lake

B. Proposed Roadway Overflow Section (None ☒) Length ____ Elev. ____ Frequency (if < 500 yr.): ____ yr.

Embankment: Soil Type ____ Type Slope Cover ____

Comments: ____

(Page 1 of2)

EXAMPLE

5. MISCELLANEOUS COMMENTS

A. Is there unusual scour potential? Yes ☒ No ☐ Protection Needed? Yes ☒ No ☐

B. Are banks stable? Yes ☒ No ☐ Protection Needed? Yes ☐ No ☒

C. Are spur dikes needed? Yes ☐ No ☒

D. Does stream carry appreciable amount of ice? Yes ☐ No ☒ Elevation of high ice________

E. Does stream carry appreciable amount of large driftwood? Yes ☒ No ☐

F. Comments Left abutment scour is significant and is confirmed by historic scour at this location, sheet pile walls will be installed to protect the abutments.

6. TRAFFIC RELATED EVALUATIONS

A. Present Year 2007 Traffic Count 530 VPD % Trucks 5

B. Design Year 2027 Traffic Count 1000 VPD % Trucks 5

C. Emergency Route Yes ☐ No ☒ School Bus Route Yes ☐ No ☒ Mail Route Yes ☐ No ☒

D. Detour Available? Yes ☒ No ☐ Length of Detour 11 Miles

Comments _____

7. PRESENT FACILITY

A. Low Roadway Elevation 868.12 ft

B. Bridge Hydraulic Capacity at point of overtopping 2,500 cfs Frequency (if Less than Q_{500}) 71 yr

Roadway Overflow: Length 900 ft. Elevation 868.12 ft.

C. Is flash flooding likely? Yes ☐ No ☒

Comments Present facility is a 20.5' x 7.25' Aluminum box culvert and was damaged beyond repair from the August 2010 flood.

8. ALTERNATIVES

A. Recommended Design 120' x 30' Continuous Concrete Slab Bridge

Low Superstructure (Bridge) 870.01 Top Opening (culvert)________

Low Roadway Grade 868.12

Bridge Waterway Opening 819 SF Culvert Opening________

B. Were other hydraulic alternates considered? Yes ☐ No ☒

Discussion 120' Bridge length required to avoid encroachment of the main channel while providing 3 feet of freeboard.

C. Is this assessment commensurate with the risks identified? Yes ☒ No ☐

or is further analysis needed? Yes ☐ No ☒

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